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Effects of Nitrogen and Potassium Fertilizers and Soil Type on Yield Components and Nutrient Uptake of Four Sugarcane Varieties

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Acknowledgments

The authors extend sincere appreciation to Mr. Roland B. Dias, General Manager of the Oaklawn Division, South Coast Corporation, for providing facilities and personnel necessary for conducting field work and obtaining field data.

Appreciation is also expressed to Dr. W. H. Willis, Professor and Head, Department of Agronomy, for guidance and assistance in conducting this research; to Dr. Barton R. Farthing, Professor and Head, Department of Experimental Statistics, for assistance in statistical analysis and interpretation of data, and to Mr. E. A. Epps, Jr., Professor and Chief Chemist, Feed and Fertilizer Laboratory, and Ms. Margaret M. Cooksey, Associate, Department of Agronomy, for assistance in chemical analyses of soil and plant samples.

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Effects of Nitrogen and Potassium Fertilizers and Soil Type on Yield Components and Nutrient Uptake of Four Sugarcane Varieties

LARON E. GOLDEN AND IDRIS B. ABDOL*

Introduction

During the 24-year period 1952-75, tests with complete fertilizers at more than 100 locations in Louisiana showed that increases in yield from fertilizers containing nitrogen (N), phosphorous (P), and potassium (K) averaged 33 percent (*12, 20, 33*)[1]. The average during 1952-63 was 33.6 percent and the average during 1964-75 was 32.5 percent. The amounts of fertilizer N, P, and K which were compared with the check, or no-fertilizer, treatments were rates recommended to sugarcane growers during the period the tests were conducted. Since growers have normally applied fertilizer at rates recommended, it appears that the amount of the total sugarcane production in Louisiana which may be attributed to application of fertilizers is approximately 25 percent, or the amount obtained experimentally.

The most marked increases in yields are usually related to requirements by cane for N. On light- to medium-textured soils, application of K is normally economically justified (*12, 32, 33*), and on medium-heavy to heavy-textured soils, P is generally economically important and sulphur (S) may also be needed (*12, 15*).

The objective of this study was to determine the relationships of fertilizer N and K rates and soil type to yield, yield components, and nutrient uptake of selected sugarcane varieties. To achieve this objective, (a) yield and yield component data were obtained; (b) soils were analyzed for macronutrient and selected micronutrient contents and pH; (c) plant materials were analyzed for macronutrient and selected micronutrient contents; and, (d) results from statistical analyses were used as bases for conclusions reported.

Review of Literature

Borden (*5*) reported that in Hawaii the highest yields of millable cane and of sugar were generally secured from high N and K fertilization rates, whereas most relatively low yields resulted from high N and low K fertilization rates. The best juice purities and sucrose-yield-percent cane were found in low N-high K treatments.

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[1] Italic numbers in parentheses refer to Literature Cited, page 59.

Lakshmikantham (*27*) found in India that increasing the level of N fertilization led to significant depression in juice sucrose content. Application of phosphate or potash, individually or in combination, to crops grown on normal soils where large quantities of nitrogenous fertilizer had been applied did not result in a significant improvement in the sucrose content of the juice.

Samuel and Landrau (*35*) found in 112 field experiments with sugarcane in Puerto Rico that N produced an increase in sucrose content with increased yields. They reported that use of potash increased sucrose concentrations in cane only if cane yields were also increased. Potassium deficiencies produced highly significant reductions in available sugar in juice. Juice extraction percentage from cane was not significantly influenced by use of potash fertilizers.

Parish (*29*) stated that in Mauritius the plant crop responded only poorly to N, the first stubble crop fairly well, and the older stubble crops extremely well. The recommended dressings of N, therefore, increased with increasing age of stubbles.

Du Toit (*10*), in South Africa, reported that N responses were more common and relatively higher in stubbles than in plant cane. The effect of N on sucrose content of cane was small when applied as an early top dressing, but late top dressing depressed the sucrose content to a highly significant degree.

Tabayoyong (*38*) conducted a series of fertilizer and variety experiments for 7 years in the Philippines to determine the effects of soil type and fertilization on the cane and sugar yields of three cane varieties. Fertilization exerted greater effects on both cane and sugar yields than did soil type. Sugar content was not affected significantly by either soil type or fertilization. Among varieties, differences in sugar content and cane and sugar yield were significant.

Wang (*41*) reported that the NPK requirements of different cane lands in Taiwan had been elucidated. The requiremnts were closely correlated with the kinds of soils. The old, strongly leached, and acid soils were deficient in plant nutrients and needed large amounts of N, P, and K fertilizers. Potash requirements were especially strong on light soils. Tests with the minor elements, manganese (Mn), zinc (Zn), copper (Cu), and molybdenum (Mo), were conducted on several soils, but no positive responses were recorded.

Patrick et al. (*30*) studied certain physical and chemical properties of the Ap horizon of three important soil series of alluvial origin in the sugarcane area in Louisiana. The soils occurred on the natural levees of the channel now occupied by Bayou Teche in South Louisiana. They found the better drained Cypremort soils, occurring at the highest elevations and closest to the stream channel, had the coarsest texture, lowest organic matter content, and the lowest aggregation. They also contained the lowest levels of mineral nutrients. The very poorly drained and finely textured Iberia soils, occupying areas furthest from the channel at the lowest elevation, were highest in organic carbon (C), percent aggregation, and content of mineral nutrients.

Patrick et al. (*31*) made a study of soil oxygen content and root development of sugarcane in Louisiana. They found that the quantities of sugarcane roots developing below the 2-foot depth were closely related to the oxygen contents of the subsoil during the first part of the growing season. In the Baldwin and Iberia soils, oxygen content in the subsoil was often at levels considered inadequate for optimum root activity.

Baver (*4*), working in Hawaii, concluded that N fertilization had a very small effect upon the percentage increase of leaf N. Potash fertilization generally had a rather pronounced effect upon the K composition of the stalk and leaf sheath tissues.

Humbert (*24*), in Hawaii, stated that when potash levels in the plant were too low, sugar began to accumulate, an indication that the cane was growing at a reduced rate. Leaf sheath K below 2.0 percent resulted in an accumulation of unused N in the leaf. Below this level, K became a limiting factor in growth. The K level at which unused N began to accumulate was about 1.5 percent.

Suggested critical amounts of N, P, K, calcium (Ca), magnesium (Mg), and S, and range of macronutrients normally found in leaf blades of sugarcane in Louisiana are as follows (*14, 15, 17, 19*):

Macronutrient	**Critical content, ppm**	**Normal range, ppm**
N	1.25	1.06 - 2.28
P	0.14	0.12 - 0.25
K	1.00	0.48 - 1.76
Ca	0.15	0.28 - 0.47
Mg	0.08	0.14 - 0.33
S	0.13	0.07 - 0.27

Additional nutrient uptake studies in Louisiana (*12, 14, 21, 22, 34*) showed that the N content of millable cane varied from 0.97 to 2.56 pounds per ton. The P content varied from 0.21 to 0.52 and the K content from 1.89 to 4.24 pounds per ton of millable cane. The Ca, Mg, and S varied from 0.18 to 0.62, 0.28 to 0.67, and 0.40 to 0.75 pound per ton of millable cane, respectively. The N, P, and K contents of above-ground growth varied from 2.75 to 4.90, 0.46 to 0.95, and 3.28 to 6.76 pounds per ton of millable cane, respectively. The Ca, Mg, and S varied from 1.21 to 2.27, 0.78 to 1.58, and 0.72 to 1.17 pounds per ton of millable cane, respectively.

In other studies in Louisiana (*18, 21*), mean N, P, and K contents of below-ground stubble and roots varied from 0.52 to 1.83, 0.10 to 0.25, and 0.64 to 1.19 pounds per ton of millable cane, respectively. The Ca, Mg, and S (*18*) varied from 0.83 to 1.32, 0.32 to 0.50, and 0.41 to 0.52 pounds per ton of millable cane, respectively. The S contents were probably considerably higher than contents of most stubble and roots in Louisiana since the soil contained an inordinately high amount of extractable S.

There are several sugarcane producing areas where natural supplies of some micronutrients are inadequate (*6*). Copper deficiencies have been found in Florida, Natal, and Queensland, and Zn deficiencies were observed in Florida and Hawaii. Manganese deficiencies were found in Guyana, and boron (B) deficiencies were observed in Nigeria. Iron (Fe) deficiency is moderately common. Though soils are generally high in Fe, Fe availability to plants may be low due to Fe-fixation in the soils. Excessive amounts of micronutrients can lead to toxicities to sugarcane. High Mn content in acidic soils in Fiji, Puerto Rico, and Hawaii, B toxicity in Peru, and Fe toxicity in Guyana's pegasse soils resulted in negative effects on growth of sugarcane. At present, tissue analysis is the primary tool for investigating the micronutrient element status of the sugarcane crop.

Andreis (*1*) found low amounts of Fe, Mn, Zn, Cu, and B removed by millable cane in Florida and noted that most soils have received high rates of Mn, Zn, and Cu during many years of cropping to sugarcane; therefore, they generally do not need additional amounts of micronutrients except possibly when the soil pH is above 6.5.

Evans (*11*) reported critical content of micronutrients in sugarcane leaf lamina, and Juang (*25*) reported critical concentration and range without deficiency symptoms in sugarcane leaf blade as follows:

	Critical content, ppm		**Range without deficiency symptoms, ppm**
Micronutrient	**Evans**	**Juang**	
Fe	5	10*	20-600
Mn	20	10*	20-400
Zn	15	15	20-100
Cu	4	5	5-100
B	1	1	2- 30
Mo	.08	.05	.05- 4

*Varies with Fe/Mn ratio. Critical level can be below 10 ppm if Fe/Mn ratio is above 1.

Sedberry et al. (*36*) reported that on land-leveled soils of the Red River alluvium, Coastal Prairies, and Coastal Plain in Louisiana Zn deficiencies were found in corn, rice, and soybeans.

Karim (*26*) studied the distribution of micronutrient cations in the genetic horizons of soils in Louisiana and found that the concentration of the total micronutrient cations appeared to vary more with the clay constituents of the soils and the amounts of the elements found in the parent materials than with soil depth. The majority of the soils studied had an accumulation of total Fe, Mn, Zn, and Cu in the B horizons; however, in the clay soils, the total micronutrient cations were concentrated in the surface horizons. Total Fe was the most abundant macronutrient cation found, followed by Mn, Zn, and Cu.

Yield data from eight field tests conducted with various individual mixtures of micronutrients since 1948 by personnel of the Louisiana Agricultural Experiment Station and the U.S. Department of Agriculture showed no beneficial effect from application of the micronutrients (*8, 9, 32*). A significant decrease in cane yield was obtained from one of the tests in which Fe, Mn, Zn, and Cu were each applied at the rate of 1.2 pounds per acre. Other micronutrients included in the field tests were B and Mo.

Golden (*13*) reported that the Fe, Mn, Zn, Cu, B, and Mo contents of leaf blades generally varied from 25 to 130, 40 to 220, 12 to 40, 5 to 35, 4 to 10, and 1.6 to 3.0 ppm, respectively. Although Zn and Cu levels were apparently near or below critical levels in some areas in Louisiana, no leaf blade or yield responses to soil or foliar applications of Zn and Cu were found.

Tonimoto and Burr (*39*) found that stalk populations depended largely on total amount of N rather than timing of application. Early applications favored primary and secondary stalk growth and late applications favored tertiary stalk growth. Cane and sugar yields also depended on total amounts of N rather than timing of application.

Studying the association among yield components in sugarcane hybrid progenies in Argentina, Mariotti (*28*) found that number of stalks per plot was most closely associated with cane yield (the r-value varied between 0.771 and 0.872). Weight per stalk was next in importance. In the study on the associations between stalk erectness and yield components, he observed that large stalk diameter was apparently related to more erect clones. Weight per stalk was the character that seemed to determine more frequently the tendency to lodge.

Sornay and Davidson (*37*) stated that, of the vegetative characters of cane, stalk length is the most important for correlating with cane yield. They found no relationship between number of tillers per plot and stalk diameter or cane yield.

Henderson et al. (*23*) obtained high correlations between number of stalks of cane in unreplicated 15-foot plots and number of stalks in larger yield trials. The high correlation coefficients indicated a strong tendency for the experimental varieties, which produced high stalk populations in 15-foot plots, also to have high average stalk numbers in the yield trials.

Materials and Methods

Experimental Design, Treatments, and Soil Type

The field portion of the study was conducted during a 3-year period beginning in 1972 at an experimental site on Oaklawn Plantation, Franklin, Louisiana. Cane was planted in 1972 at the rate of two continuous stalks and a 15 percent overlap. Yield component and chemical data were obtained in 1973 from plant cane and in 1974 from first stubble cane.

The study consisted of 48 plots arranged in a randomized complete block design in which four cane varieties and four fertilizer treatments were located in three replicates. The varieties were CP52-68, L60-25, L62-96, and L65-69. Fertilizers applied to plant cane in pounds per acre of N, P_2O_5, and K_20 were 80-0-0, 80-0-80, 160-0-0, and 160-0-80. Fertilizers applied to the first stubble cane were 120-0-0, 120-0-80, 240-0-0, and 240-0-80. No fertilizer P was applied since there was a residual effect from P in filter press mud which was applied to the area approximately 20 years earlier. One replicate of treatments was located on Baldwin silt loam (Soil I), another on Baldwin silt loam-Iberia clay (Soil II), and a third on Iberia clay (Soil III). Each plot consisted of three rows that were 70 inches wide and 100 feet long.

Nitrogen, as ammonium nitrate, and K, as muriate of potash, were applied in the off-bar furrow in April of each crop year.

Determination of Cane Population

In the plant cane year, 1973, a segment of the center row of each plot 30 feet in length was staked for cane population determination and for obtaining yield data. In the first stubble cane year, 1974, the 30-foot segment of the center row was relocated within each plot to minimize a possible variation in effect of date of harvest of plant cane on first stubble cane yield.

During the period May through August of each crop year counts were made at approximately one-month intervals to determine the total plant population in each plot. September counts were estimates of the number of stalks that possibly would be of millable size. At the beginning of the first harvest, in early October of each crop year, counts were conducted to determine the number of millable stalks in each plot.

Harvesting and Determination of Certain Cane Components

Harvests were accomplished in the first week of October, the first week of November, and the last week of November of each crop year. The stalks were cut by hand at the ground line and were carried to open areas for further processing.

Cane yields were calculated from millable cane population and stalk weight data.

First Harvest — The first harvest of plant cane was conducted October

3-6, 1973. The first harvest of first stubble cane was conducted October 3-5, 1974. In each plot, a 20-stalk sample was selected at random from the millable cane on the 30-foot segment of row which was established for determination of cane population and yield data.

After removal of leaves, each cane stalk was cut at the top hard joint, which was 20-22 inches from the top visible dewlap (TVD). Stalk samples were weighed and the length and diameter of each stalk were determined. Sucrose analyses were made by Oaklawn Sugar Factory.

Second Harvest — The second harvest of the plant cane was conducted November 5-7, 1973, and the second harvest of first stubble cane was conducted November 2-3, 1974. Six-stalk samples were randomly selected from the same sites sampled at the first harvest. As a practical consideration, it was necessary that the second-harvest samples consist of a relatively small number of stalks since processing was done 100 miles away at the St. Gabriel Experiment Station, Baton Rouge. In addition to similar data collected from other harvests, samples from the second harvest were used to obtain nutrient uptake data.

At the St. Gabriel Experiment Station, the six-stalk samples consisting of all above-ground parts were weighed. After removal of leaves, each stalk was cut at the top hard joint, 16-18 inches from the TVD. Each stalk sample was weighed, and the green weight of tops and trash was obtained by difference. The length and diameter of each stalk were determined. Juice was extracted from the stalk samples and weighed. The green weight of bagasse was obtained by difference. The juice extraction percentage was obtained by dividing juice weight by sample weight.

Juice samples were analyzed for sucrose content at the St. Gabriel Experiment Station, and subsamples were frozen and maintained in a frozen state until nutrient contents were determined. Subsamples of green tops and trash and of bagasse were weighed and were dried in a forced draft oven at 70°C for 48 hours. The dry subsamples of tops and trash and of bagasse were weighed, were ground in a large Wiley mill without use of a sieve, and a portion of each subsample was further ground in a small Wiley mill to pass a 20-mesh sieve. Following sieving, the plant materials were dried 2 hours in a convection oven and were stored in glass bottles for chemical analyses. Yields of juice, tops and trash, and bagasse were calculated from cane yields and weights of plant materials obtained during processing.

Third Harvest — The third harvest of the plant cane was conducted November 29-30, 1973. The third harvest of the first stubble cane was conducted November 24-25, 1974. Stalk samples in the first and third harvests were obtained by similar methods.

After removal of leaves, each cane stalk was cut at the top hard joint, 14-16 inches from the TVD. Stalk samples were weighed and the length and diameter of each stalk were determined. Sucrose analyses were made by Oaklawn Sugar Factory.

Determination of Degree of Stalk Lodging

Lodging was rated on a scale of 0 to 10, 0 indicating no lodging at all in the field, and 10 indicating that all the stalks were lodged. The determinations were made subjectively by visual observation.

Soil and Plant Material

In the spring of 1973, soil samples were collected from each plot prior to the applications of N and K fertilizers. The topsoil samples were taken at a depth of 0-7 inches, and the subsoil samples were taken at a depth of 7-24 inches.

Leaf blade samples were taken from each plot in early July of each crop year. The leaf blades were obtained from the first leaf below the TVD. Each sample, consisting of 15 leaf blades, was dried in a forced draft oven at 70°C for 24 hours. The leaf blades were ground in a small Wiley mill to pass a 20-mesh sieve. Following sieving, the samples were dried 2 hours in a convection oven and were stored in glass bottles for chemical analyses.

Samples of juice, tops and trash, and bagasse were obtained at the second harvest each crop year and were processed for chemical analyses as previously described.

Soil and Plant Analysis Procedures

Organic C in soils was determined by the Walkley-Black (*40*) "wet-combustion" method, and total N in soil and plant samples was determined by the modified Kjeldahl method. "Soil" and extractable S were determined according to procedures described by Bardsley and Lancaster (*3*), and total S in plant samples was determined by the magnesium nitrate method (*2*). From soils, pH and the amounts of extractable P, K, Ca, and Mg were obtained using the method of Brupbacher et al. (*7*) as modified to use a Perkin-Elmer Model 303 atomic absorption spectrometer. Extractable Fe, Mn, Zn, and Cu were obtained by using the same extract (0.1 N HCl) as was used for K, Ca, and Mg. Plant materials were digested in a 4:1 mixture of concentrated nitric and perchloric acids for the determination of P, K, Ca, Mg, Fe, Mn, Zn, and Cu. With the exception of P, the amounts of these elements in plant samples were determined by use of the atomic absorption spectrometer. The amounts of P in plant samples were obtained by the chlorostannous-reduced molybdophosphoric blue color method in a hydrochloric acid system.

Statistical Analyses

Analyses of variance were obtained each crop year for the variables that were studied during the year. Simple correlation coefficients were obtained among all variables which were considered to be of possible agronomic importance.

Results and Discussion

Means of results from chemical analyses of soil samples collected from the experimental area and statistical information obtained from the data are presented in Tables 1 through 5. Information concerning shoot and/or stalk population, juice extraction, and lodging is presented only in narrative form. Tables 6 through 18 and Figure 1 show mean yield, yield component, and correlation data. Table 19 contains mean tops and trash, bagasse, and juice yields. In Tables 20 through 29, information concerning macronutrient contents of plant materials and correlations is presented. Micronutrient contents of the plant materials and related correlation coefficients are contained in Tables 30 through 35.

Generally, interactions among treatment effects on the data are discussed only when they were statistically significant.

Soil Nutrient Contents and Correlations Among Soil Nutrients and pH

Organic C, Total N, "Soil" S, Extractable S, P, K, Ca, and Mg, and Soil pH. — It can be seen in Tables 1 and 2 that the organic C and macronutrient contents of topsoil, with the exception of extractable P, were statistically higher in Soil III than in Soil I and were generally intermediate in Soil II. The subsoil extractable P, K, Ca, and Mg contents were also statistically higher in Soil III than in Soil I, but organic C and total N were statistically lower in Soil III than in Soil I. No tabular data are shown for

Table 1. — Means of organic C, total N, "Soil" S, and extractable S contents of topsoil (T) and subsoil (S) as related to soil type

Variable	Organic C		Total N		"Soil" S		Extractable S	
	T	S	T	S	T	S	T	S
	- - - - - - - - %	- - - - - - -			- - - - - - ppm	- - - - - - - -		
Soil I	1.138	.760	.101	.065	132	86	5.2	6.7
Soil II	1.288	.695	.109	.065	152	93	8.2	8.8
Soil III	1.411	.631	.114	.059	155	82	9.8	7.7
LSD .05	.040	.102	.003	.006	11	NS	1.7	1.3

Table 2. — Means of extractable P, K, Ca, and Mg contents of topsoil (T) and subsoil (S) as related to soil type

Variable	Extractable P		Extractable K		Extractable Ca		Extractable Mg	
	T	S	T	S	T	S	T	S
	- - - - - - -	- - - - - - - -	- - - - - - - - ppm-	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -
Soil I	147	61	131	194	2808	3069	612	1251
Soil II	165	164	172	202	3818	3908	827	1295
Soil III	157	165	190	225	4299	4840	804	1545
LSD .05	NS	24	21	25	288	379	101	122

variety and fertilizer treatments since minimal bias was indicated by small and generally nonsignificant differences among means.

Simple correlation coefficients among organic C, macronutrient contents, and pH of soils are presented in Table 3. In the topsoil positive and highly significant correlations were found among organic C, total N, "Soil" S and extractable S, K, and Ca. Except for extractable P, soil pH was correlated to a highly significant degree with organic C and macronutrient contents of the topsoil. Correlation coefficients among extractable K, Ca, and Mg were highly significant. Extractable P did not correlate with any of the chemical properties of the topsoil shown in Table 3. Extractable Mg in the topsoil correlated with organic C and "Soil" S at the 5 percent level of probability. In the subsoil positive and highly significant correlations were obtained among organic C, total N, and "Soil" S. Statistically significant correlations were found among extractable K, Ca, and Mg in the subsoil.Subsoil pH was negatively related to organic C and positively related to extractable S, P, Ca, and Mg. Unlike in the topsoil, extractable P in the subsoil showed a good degree of relationship to extractable S and Ca. The correlation between "Soil" S and extractable S in the subsoil was highly significant.

Table 3. — Correlation coefficients (r)[1] among organic C contents, macronutrient contents, and pH of soils

	Total N	"Soil" S	Ext. S	Ext. P	Ext. K	Ext. Ca	Ext. Mg	pH
			Topsoil					
Organic C	.883	.681	.677	.222	.576	.780	.359	.749
Total N		.659	.563	.255	.433	.614	.284	.568
"Soil" S			.671	.083	.468	.606	.310	.702
Ext. S				.185	.430	.650	.214	.652
Ext. P					-.214	-.050	-.158	.138
Ext. K						.862	.865	.596
Ext. Ca							.671	.802
Ext. Mg								.410
			Subsoil					
Organic C	.930	.796	.043	-.231	-.148	-.030	.030	-.286
Total N		.829	.176	-.166	-.069	.004	.056	-.199
"Soil" S			.397	.059	-.096	.200	.117	.023
Ext. S				.351	-.110	.201	-.116	.350
Ext. P					-.045	.631	.236	.862
Ext. K						.503	.797	.245
Ext. Ca							.796	.831
Ext. Mg								.478

[1] Least significant r at 1% level = .369. Least significant r at 5% level = .285.

Table 4. — Means of extractable Fe, Mn, Zn, and Cu contents of topsoil (T) and subsoil (S) as related to soil type

	Extractable Fe		Extractable Mn		Extractable Zn		Extractable Cu	
Variable	T	S	T	S	T	S	T	S
	ppm							
Soil I	84	51	71	59	4.1	6.0	3.1	4.7
Soil II	72	104	95	94	4.6	6.7	2.7	3.6
Soil III	64	68	77	83	3.7	5.2	1.6	1.7
LSD .05	11	15	6	9	NS	NS	.9	.8

Extractable Fe, Mn, Zn, and Cu, and Soil pH. — It may be noted in Table 4 that mean extractable Fe content of the topsoil was of the general order: Soil I > Soil II > Soil III, but in the subsoil, it was highest in Soil II and lowest in Soil I. Manganese in topsoil and subsoil was of the order: Soil II > Soil III > Soil I. Differences among Soils I, II, and III in mean Zn content were not significant. Copper in topsoil and in subsoil was of the general order: Soil I > Soil II > Soil III. Practically no bias existed among variety and fertilizer treatments which may be attributed to extractable micronutrient contents of soils on which the treatments were established, hence, no tabular data are shown.

Simple correlation coefficients among organic C, micronutrient contents, and pH of soils are shown in Table 5. In the topsoil, extractable Fe was negatively correlated with organic C, and in the subsoil, it was

Table 5. — Correlation coefficients (r)[1] among organic C contents, micronutrient contents and pH of soils

	Ext. Fe	Ext. Mn	Ext. Zn	Ext. Cu	pH
		Topsoil			
Organic C	-.356	.122	-.193	-.526	.749
Ext. Fe		.038	.189	.291	-.261
Ext. Mn			.151	.019	.457
Ext. Zn				.840	.001
Ext. Cu					-.331
		Subsoil			
Organic C	-.161	-.215	.054	.060	-.286
Ext. Fe		.683	.238	.049	.344
Ext. Mn			-.016	-.376	.626
Ext. Zn				.455	-.031
Ext. Cu					-.662

[1] Least significant r at 1% level = .369. Least significant r at 5% level = .285.

positively correlated with extractable Mn. The relationship of extractable Cu to organic C in topsoil was negative, and to extractable Fe and Mn was positive. The relationship of subsoil extractable Cu to extractable Mn was negative, but to extractable Zn was positive. In the topsoil and subsoil, positive correlations were found between soil pH and extractable Mn, and negative correlations were found between soil pH and extractable Cu. A positive correlation was obtained between soil pH and organic C in the topsoil, but the relationship was negative in the subsoil. A positive correlation existed between pH and extractable Fe in the subsoil, but in the topsoil, the relationship was negative and approached significance.

Shoot and/or Stalk Population

Counts of the total number of plant and first stubble shoots and stalks per acre were made monthly from May through August. In September, counts were made to estimate the number of stalks that possibly would be of millable size. In October, the actual number of millable stalks was determined.

Plant Cane. — From May to September the numbers of shoots and/or stalks from L60-25 and L65-69 were consistently higher than the numbers from CP52-68 and L62-96. The number of millable stalks was of the order: L60-25 > L65-69 > CP52-68 > L62-96.

The numbers of millable stalks from the 80-0-0, 80-0-80, 160-0-0, and 160-0-80 treatments were 27,200, 29,070, 27,900,and 29,680 per acre, respectively.

Although shoot and stalk counts among soils in June and July were of the order: Soil II > Soil III > Soil I, the numbers of millable stalks among soil types did not differ appreciably.

First Stubble Cane. — From June to October, the order of the number of shoots and/or stalks from stubble cane was: L60-25 > L65-69 > CP52-68 > L62-96, or was of the same general order as in plant cane.

The numbers of millable stalks from the 120-0-0, 120-0-80, 240-0-0, and 240-0-80 treatments were 28,710, 31,030, 30,410, and 32,280 per acre, respectively.

Differences in number of shoots and/or stalks due to soil type were generally small throughout the growing season.

Yield as Related to Variety

Tables 6 and 7 contain mean cane and sugar yields and normal juice data as related to varieties. Significant interactions between varieties and harvest periods influenced sugar yield and sucrose content of stubble cane.

Plant Cane. — It may be noted in Table 6 that cane yield from the plant cane crop of each variety increased in approximately equal increments from Harvest 1 to Harvest 2 and from Harvest 2 to Harvest 3. Incremental increases from Harvest 1 to Harvest 2 in sugar yield were substantially

Table 6. — Effect of harvest period as an average of four fertilizer treatments and three soil types on the yield of sugarcane and sugar from four varieties of plant cane

Variety	Harvest period	Cane[1] yield	Normal juice Brix	Normal juice Sucrose[2]	Normal juice Purity	Sugar[3] yield
		T/A	%	%	%	Lb/A
CP 52-68	1	30.36	13.10	8.63	65.88	3273
	2	33.98	15.25	11.30	74.10	5213
	3	37.57	16.19	12.61	77.89	6605
Average		33.97	14.85	10.85	72.62	5030
L 60-25	1	31.60	14.90	11.36	76.24	4882
	2	35.26	17.15	14.13	82.39	7115
	3	38.00	17.76	14.78	83.22	8090
Average		34.95	16.60	13.42	80.62	6696
L 62-96	1	32.50	15.90	12.06	75.85	5408
	2	36.34	17.44	14.39	82.51	7497
	3	40.61	18.27	15.01	82.16	8808
Average		36.48	17.20	13.82	80.17	7238
L 65-69	1	33.42	16.11	11.56	70.76	5277
	2	36.98	17.71	14.42	81.42	7647
	3	40.74	18.05	14.75	81.72	8653
Average		37.05	17.29	13.58	77.97	7192

[1] For comparison of cane yield averages, LSD .05 = 1.31.
For comparison of cane yields among harvest periods, LSD .05 = 2.76.

[2] For comparison of sucrose averages, LSD .05 = .33.
For comparison of sucrose contents among harvest periods, LSD .05 = .58.

[3] For comparison of sugar yield averages, LSD .05 = 310.
For comparison of sugar yields among harvest periods, LSD .05 = 539.

larger than increases from Harvest 2 to Harvest 3. Sucrose content of normal juice of each variety at Harvest 2 was higher than at Harvest 1, and, with the exception of L65-69, the sucrose of each variety at Harvest 3 was higher than at Harvest 2.

The difference between average cane yields from CP52-68 and L60-25 was not significant. Likewise, average cane yields from L62-96 and L65-69 did not differ statistically but were statistically higher than from

CP52-68 and L60-25. The difference in average sugar yield from L62-96 and L65-69 was not significant. The average sugar yields from L62-96 and L65-69 were statistically higher than the averages from the other two varieties. The average sugar yield from L60-25 was statistically higher than the yield obtained from CP52-68.

The average sucrose content of normal juice from L62-96 was statistically higher than sucrose from L60-25 and CP52-68, but although it was

Table 7. — Effect of harvest period as an average of four fertilizer treatments and three soil types on the yield of sugarcane and sugar from four varieties of first stubble cane

Variety	Harvest period	Cane[1] yield	Normal juice Brix	Normal juice Sucrose[2]	Normal juice Purity	Sugar[3] yield
		T/A	%	%	%	Lb/A
CP 52-68	1	31.99	15.23	9.59	62.97	3980
	2	37.37	17.02	12.46	73.21	6465
	3	37.16	17.30	13.72	79.31	7223
Average		35.51	16.52	11.93	71.83	5889
L 60-25	1	34.60	17.77	12.99	73.10	6313
	2	39.79	18.31	14.68	80.17	8409
	3	39.26	18.55	15.38	82.91	8745
Average		37.88	18.21	14.35	78.73	7822
L 62-96	1	30.13	18.31	12.92	70.56	5463
	2	34.65	19.16	15.25	79.59	7606
	3	34.95	19.25	16.12	83.74	8214
Average		33.24	18.91	14.76	77.96	7094
L 65-69	1	32.81	17.92	11.18	62.39	4969
	2	41.05	19.40	14.99	77.27	8867
	3	38.26	19.31	15.86	82.13	8827
Average		37.37	18.88	14.01	73.93	7555

[1] For comparison of cane yield averages, LSD .05 = 1.64.
For comparison of cane yields among harvest periods, LSD .05 = 2.83.

[2] For comparison of sucrose averages, LSD .05 = .28.
For comparison of sucrose among harvest periods, LSD .05 = .49.

[3] For comparison of sugar yield averages, LSD .05 = 336.
For comparison of sugar yields among harvest periods, LSD .05 = 581.

higher, it did not differ statistically from L65-69 normal juice sucrose. The late maturing variety, CP52-68, showed the greatest increase in sucrose between Harvests 1 and 3 (3.98 percentage points); nevertheless, sucrose at Harvest 3 for CP52-68 was substantially lower than sucrose from other varieties.

First Stubble Cane. — Significant increases in stubble cane yield (Table 7) were obtained from each variety at Harvest 2, when compared to Harvest 1, but cane yield at Harvest 3 did not differ significantly from cane yield at Harvest 2.

Sugar yield and sucrose from all varieties were significantly higher at Harvest 2 than at Harvest 1. Although sucrose from all varieties was significantly higher at Harvest 3 than at Harvest 2, only CP52-68 and L62-96 produced higher sugar yields at Harvest 3 when compared to Harvest 2. The variety x harvest period interaction which influenced sucrose content was noted primarily in relatively large sucrose increases from CP52-68 and L65-69 at Harvest 2 as compared with Harvest 1. The variety x harvest period interaction which influenced sugar yield was noted primarily in relatively large sugar yield increases from CP52-68 and L62-96 at Harvest 3 as compared with Harvest 2.

The differences in average cane and sugar yields from L60-25 and L65-69 were not significant. However, both varieties showed significantly higher average yields of cane and sugar than CP52-68 and L62-69. The cane yield average from CP52-68 was higher than the average from L62-96, but the sugar yield average was lower due to low sucrose content of CP52-68. The average sucrose content of normal juice was of the order: L62-96 > L60-25 > L65-69 > CP52-68.

Yield as Related to Fertilizer N and K

Tables 8 through 13 contain information concerning the effect of fertilizer N and K on mean cane and sugar yields and sucrose content of normal juice. Significant interactions occurred between varieties and N which affected cane and sugar yields and sucrose content of stubble cane. Other significant interactions were variety x K on sugar yield and sucrose content, and variety x N x K on sugar yield of stubble cane.

Table 8. — Effect of fertilizers as an average of four varieties and three soil types on the yield of sugarcane and sugar at three harvest periods of plant cane

Fertilizer $N-P_2O_5-K_2O$	Harvest period	Cane[1] yield	Normal juice Brix	Normal juice Sucrose[2]	Normal juice Purity	Sugar[3] yield
Lb/A		T/A	%	%	%	Lb/A
80-0-0	1	31.01	15.09	10.72	71.04	4450
	2	34.26	16.63	13.18	79.25	6359
	3	38.10	17.67	14.32	81.04	7814
Average		34.46	16.43	12.74	77.11	6208
80-0-80	1	32.56	15.06	10.96	72.78	4806
	2	36.04	17.08	13.65	79.92	6977
	3	40.18	17.62	14.34	81.38	8253
Average		36.26	16.59	12.98	78.03	6679
160-0-0	1	31.67	15.19	10.74	70.70	4557
	2	35.52	16.93	13.63	80.51	6866
	3	38.94	17.49	14.25	81.48	7940
Average		35.38	16.54	12.87	77.56	6454
160-0-80	1	32.65	15.23	11.20	73.53	4953
	2	36.72	16.87	13.78	81.68	7190
	3	39.71	17.57	14.24	81.05	8089
Average		36.36	16.56	13.07	78.76	6744

[1] For comparison of cane yield averages, LSD .05 = 1.31.
For comparison of cane yields among harvest periods, LSD .05 = 2.76.

[2] For comparison of sucrose averages, LSD .05 = .33.
For comparison of sucrose contents among harvest periods, LSD .05 = .58.

[3] For comparison of sugar yield averages, LSD .05 = 310.
For comparison of sugar yields among harvest periods, LSD .05 = 539.

Table 9. — Effect of fertilizer N as an average of two levels of fertilizer K, three soil types, and three harvest dates on the yield of sugarcane and sugar from four varieties of plant cane

Variety	Fertilizer N	Cane yield	Normal juice			Sugar yield
			Brix	Sucrose	Purity	
	lb/A	T/A	%	%	%	Lb/A
CP 52-68	80	32.91	15.00	10.86	72.40	4839
	160	35.03	14.87	10.83	72.83	5169
L 60-25	80	35.13	16.46	13.22	80.32	6561
	160	34.78	16.84	13.63	80.94	6777
L 62-96	80	36.61	17.35	13.89	80.06	7319
	160	36.36	17.12	13.75	80.32	7163
L 65-69	80	36.79	17.38	13.47	77.50	7074
	160	37.31	17.44	13.68	78.44	7304
LSD .05		1.85		.48		440

Plant Cane. — It may be noted in Table 8 that the higher rate of fertilizer N did not produce significant increases in average cane yield. However, due to some interaction, the higher level of N produced a significant increase in cane yield from CP52-68 (Table 9).

Data in Table 8 indicate a significant increase in average cane yield due to fertilizer K only at the lower level of N. Increases from individual varieties due to K were not significant (Table 10), but, collectively, the response was 1.39 tons per acre and was highly significant.

Sugar yields from the two levels of N as averages of all other variables did not differ statistically.

It can be seen in Table 8 that fertilizer K at the lower level of N produced a significant increase in average sugar yield. The increase due to K at the higher level of N approached significance. Additionally, in Table 10 it can be seen that, as an average of the two levels of N and of all soil types and harvest dates, K produced statistically higher sugar yields from L60-25 and L62-96. The higher sugar yield due to K applied to L65-69 approached significance (Table 10). As an average of all other variables, the response in sugar yield due to K was 382 pounds per acre and was highly significant.

As averages of all other variables, sucrose contents of normal juice from cane fertilized with the two rates of N did not differ statistically.

As an average of all other variables, the normal juice sucrose content of cane from the K treatment was 0.22 percentage point higher than the check and approached statistical significance. The F value was 3.37. The required F value for significance at the 5 percent level of probability was 3.95.

Table 10. — Effect of fertilizer K as an average of two levels of fertilizer N, three soil types, and three harvest dates on the yield of sugarcane and sugar from four varieties of plant cane

Variety	Fertilizer K_2O	Cane yield	Normal juice Brix	Normal juice Sucrose	Normal juice Purity	Sugar yield
	Lb/A	T/A	%	%	%	Lb/A
CP 52-68	0	33.55	14.96	10.82	72.33	4953
	80	34.39	14.91	10.87	72.90	5055
L 60-25	0	34.14	16.53	13.30	80.46	6434
	80	35.76	16.76	13.54	80.79	6905
L 62-96	0	35.61	17.14	13.64	79.58	6968
	80	37.36	17.35	14.01	80.75	7514
L 65-69	0	36.38	17.40	13.47	77.41	6984
	80	37.73	17.43	13.69	78.54	7394
LSD .05		1.85		.48		440

First Stubble Cane. — Average cane yield from the 240-0-0 treatment was higher than from the 120-0-0 treatment (Table 11). Likewise, cane yield from the 240-0-80 treatment was higher than from the 120-0-80 treatment. However, a significant variety x N interaction effect on cane yield occurred (Table 12) which is shown by significant increases in yields from L62-96 and L65-69 due to the higher level of N and no significant effect of the higher level of N on cane yields from L60-25 and CP52-68.

Fertilizer K produced an increase in average cane yield at each level of N (Table 11). Although differences in responses to K among varieties were found (Table 13), the variety x K interaction effect on cane yield was not significant.

The sugar yield average from the 240-0-0 treatment (Table 11) was not significantly higher than from the 120-0-0 treatment, primarily due to a significant decrease in average sucrose content of normal juice from cane which received the higher N treatment. Sugar yield from the 240-0-80 treatment was significantly higher than from the 120-0-80 treatment.

The variety x N interaction effect on sugar yield is shown in Table 12. From L65-69, the higher N level produced higher sugar yield. The higher yield from L62-96 and the lower yield from CP52-68 at the higher N level approached significance. The small difference in sugar yield from N treatments applied to L60-25 was not significant.

Fertilizer K produced an increase in average sugar yield at each level of N (Table 11), but a variety x K interaction occurred, and the effect on sugar yield may be noted in Table 13. The sugar yield responses to K by L60-25 and L62-96 were highly significant, the response by L65-69 was significant, and the response by CP52-68 was not significant.

Table 11. — Effect of fertilizers as an average of four varieties and three soil types on the yield of sugarcane and sugar at three harvest periods of first stubble cane

Fertilizer N-P_2O_5-K_2O	Harvest period	Cane[1] yield	Normal juice			Sugar[3] yield
			Brix	Sucrose[2]	Purity	
Lb/A		T/A	%	%	%	Lb/A
120-0-0	1	30.29	17.40	11.78	67.70	4875
	2	36.09	18.62	14.35	77.07	7371
	3	34.59	18.73	15.35	81.95	7651
Average		33.66	18.25	13.83	75.57	6632
120-0-80	1	32.89	17.20	11.85	68.90	5352
	2	37.77	18.49	14.53	78.58	7833
	3	38.66	18.71	15.35	82.04	8570
Average		36.44	18.13	13.91	76.51	7252
240-0-0	1	31.32	17.18	11.26	65.54	4810
	2	38.19	18.33	14.12	77.03	7733
	3	36.75	18.50	15.22	82.27	8097
Average		35.42	18.00	13.53	74.95	6880
240-0-80	1	35.02	17.42	11.80	67.74	5689
	2	40.81	18.53	14.38	77.60	8409
	3	39.62	18.56	15.17	81.73	8692
Average		39.48	18.17	13.78	75.69	7597

[1] For comparison of cane yield averages, LSD .05 = 1.64.
For comparison of cane yields among harvest periods, LSD .05 = 2.83.

[2] For comparison of sucrose averages, LSD .05 = .28.
For comparison of sucrose contents among harvest periods, LSD .05 = .49.

[3] For comparison of sugar yield averages, LSD .05 = 336.
For comparison of Sugar yields among harvest periods, LSD .05 = 581.

Sugar yield data showing the variety x N x K interaction are contained in Tables 12 and 13. The positive effect of the higher N level on sugar yield from varieties was of the order: L65-69 > L62-96 > L60-25 > L52-68 (Table 12), whereas the positive effect of fertilizer K on sugar yield was of the order: L60-25 > L62-96 > L65-69 > CP52-68 (Table 13).

Table 12. — Effect of fertilizer N as an average of two levels of fertilizer K, three soil types, and three harvest dates on the yield of sugarcane and sugar from four varieties of first stubble cane

Variety	Fertilizer N	Cane yield	Normal juice Brix	Normal juice Sucrose	Normal juice Purity	Sugar yield
	lb/A	T/A	%	%	%	Lb/A
CP 52-68	120	36.19	16.72	12.12	72.49	6119
	240	34.82	16.61	11.73	70.62	5659
L 60-25	120	37.25	18.07	14.44	79.91	7759
	240	38.52	18.14	14.26	78.61	7886
L62-96	120	31.50	19.22	15.03	78.20	6866
	240	34.98	18.66	14.50	77.71	7323
L65-69	120	35.26	18.87	13.87	73.50	7024
	240	39.49	19.04	14.15	74.32	8085
LSD .05		2.31		.40		475

Table 13. — Effect of fertilizer K an an average of two levels of fertilizer N, three soil types, and three harvest dates on the yield of sugarcane and sugar from four varieties of first stubble cane.

Variety	Fertilizer K_2O	Cane yield	Normal juice Brix	Normal juice Sucrose	Normal juice Purity	Sugar yield
	Lb/A	T/A	%	%	%	Lb/A
CP 52-68	0	34.27	16.93	12.16	71.83	5824
	80	36.74	16.40	11.69	71.28	5954
L 60-25	0	35.40	18.02	14.22	78.91	7222
	80	40.37	18.18	14.48	79.65	8423
L 62-96	0	31.90	18.87	14.48	76.74	6669
	80	34.58	19.00	15.05	79.21	7520
L65-69	0	36.58	18.83	13.86	73.61	7310
	80	38.16	19.09	14.17	74.23	7799
LSD .05		2.31		.40		475

The variety x N interaction effect on sucrose content of normal juice may be noted in Table 12. Sucrose from L62-96 decreased significantly due to the higher level of N. The decrease from CP52-68 and the increase from L65-69 approached significance. Sucrose difference due to the two levels of N applied to L60-25 was not significant.

The variety x K interaction on sucrose can be seen in Table 13. Sucrose from L62-96 increased significantly and sucrose from CP52-68 decreased significantly due to K. Although positive, the effects of K on sucrose from L60-25 and L65-69 were not significant.

Fertilizer K and Early-Maturing Varieties. — A summary of the positive effect of fertilizer K on mean sucrose from the early-maturing varieties, L60-25, L62-96, and L65-69, is shown in Figure 1. The effect was generally constant in plant and stubble cane until about mid-November.

On light- to medium-textured soils, in addition to increases in cane yield, there is a substantial tendency for cane, particularly stubble cane, of early-maturing or high-sucrose varieties to contain higher amounts of sucrose due to fertilizer K. This was shown in eight additional field tests on Commerce silt loam in Louisiana during 1972-75 (*12*). Varieties tested were CP61-37, CP48-103, L62-96, L65-69, and CP65-357. In early October the average increase in sucrose content of normal juice from seven tests with stubble cane was 0.57 percentage point and in early November the average increase was 0.28 percentage point. Each increase was highly significant.

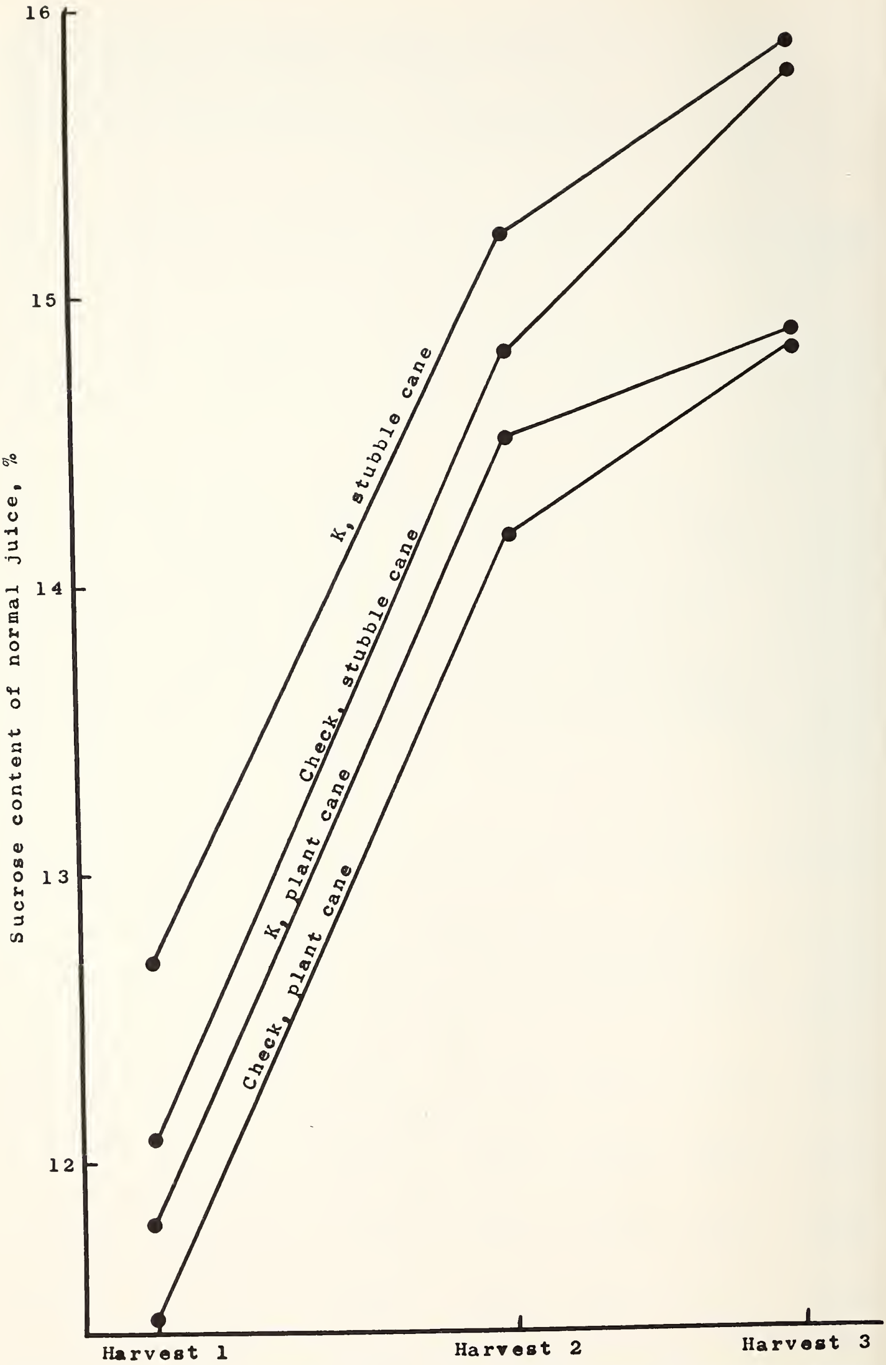

Figure 1. — The effect of fertilizer K on sucrose content of normal juice from the early maturing varieties, L60-25, L62-96, and L65-69

Yield and Sucrose as Related to Soil Type

Tables 14 and 15 show mean cane and sugar yields and normal juice data as related to soil type.

Plant Cane. — It may be noted in Table 14 that cane yield averages were higher from Soils I and II than from Soil III.

Although sugar yield averages were of the order: Soil III > Soil II > Soil I, only the difference between averages from Soils I and III was statistically significant.

Sucrose content of normal juice from cane on Soil III was higher than from cane on Soils I and II.

Table 14. — Effect of soil type as an average of four varieties and four fertilizer treatments on the yield of sugarcane and sugar at three harvest periods of plant cane

Soil	Harvest period	Cane[1] yield	Normal juice Brix	Normal juice Sucrose[2]	Normal juice Purity	Sugar[3] yield
		T/A	%	%	%	Lb/A
Baldwin sil (Soil I)	1	32.04	14.24	10.41	73.10	4428
	2	35.89	16.52	13.22	80.02	6686
	3	40.05	17.25	14.04	81.39	8022
Average		35.99	16.00	12.56	78.17	6379
Baldwin sil- Iberia c (Soil II)	1	32.73	15.05	10.64	70.70	4651
	2	35.41	16.76	13.41	80.01	6710
	3	40.02	17.57	14.26	81.16	8164
Average		36.05	16.46	12.77	77.29	6508
Iberia c (Soil III)	1	31.14	16.02	11.65	72.72	4964
	2	35.68	17.44	14.01	80.33	7129
	3	37.62	17.95	14.57	81.17	7874
Average		34.81	17.14	13.41	78.08	6656

[1] For comparison of cane yield averages, LSD .05 = 1.13.
For comparison of cane yields among harvest periods, LSD .05 = 1.96.

[2] For comparison of sucrose averages, LSD .05 = .29.
For comparison of sucrose contents among harvest periods, LSD .05 = .50.

[3] For comparison of sugar yield averages, LSD .05 = 269.
For comparison of sugar yields among harvest periods, LSD .05 = 466.

First Stubble Cane. — Data in Table 15 show cane yield averages from the first stubble crop were of the order: Soil I > Soil II > Soil III. The difference between averages from Soils I and II approached significance, and the difference between Soils I and III was significant.

The sugar yield average from Soil II was significantly higher than from Soil I. The differences in averages from Soils II and III and from Soils I and III were not significant.

Average sucrose contents of normal juice from Soils II and III were approximately equal and were significantly higher than from Soil I.

Sucrose and Soil Type. — Since sucrose from cane on Soil III (Iberia clay) was higher than sucrose from cane on Soil I (Baldwin silt loam) in 1973 and 1974, samples from the plots were taken from second stubble

Table 15. — Effect of soil type as an average of four varieties and four fertilizer treatments on the yield of sugarcane and sugar at three harvest periods of first stubble cane

Soil	Harvest period	Cane[1] yield	Normal juice			Sugar[3] yield
			Brix	Sucrose[2]	Purity	
		T/A	%	%	%	Lb/A
Baldwin sil (Soil I)	1	32.66	17.26	10.83	62.75	4755
	2	39.40	17.90	13.58	75.87	7581
	3	39.67	18.16	14.89	81.99	8513
Average		37.24	17.77	13.10	73.54	6950
Baldwin sil- Iberia c (Soil II)	1	32.26	17.19	12.10	70.39	5394
	2	38.58	18.73	14.63	78.11	8110
	3	36.69	18.86	15.53	82.34	8274
Average		35.84	18.26	14.09	76.95	7259
Iberia c (Soil III)	1	32.23	17.43	12.08	69.31	5379
	2	36.66	18.84	14.83	78.72	7831
	3	35.85	18.85	15.40	81.70	8005
Average		34.91	18.37	14.10	76.58	7072

[1] For comparison of cane yield averages, LSD .05 = 1.42.
For comparison of cane yields among harvest periods, LSD .05 = 2.45.

[2] For comparison of sucrose averages, LSD .05 = .24.
For comparison of sucrose contents among harvest periods, LSD .05 = .42.

[3] For comparison of sugar yield averages, LSD .05 = 291.
For comparison of sugar yields among harvest periods, LSD .05 = 504.

cane in 1975 with the result that the trend was reversed, or sucrose from Soil III was lower than from Soil I. These observations, together with mixed results from additional similar work on soils near the Mississippi River in 1975, justify the conclusion that no general trend appears to exist concerning sucrose content of cane grown on light- as opposed to heavy-textured soils in Louisiana.

Stalk Weight, Length, and Diameter

Except at Harvest 2 of first stubble cane, mean stalk weights of plant and stubble cane at all harvests (Tables 16 and 17) were of the order: L62-96 > L65-69 = CP52-68 > L60-25. The deviation from the normal order of stalk weights among varieties at Harvest 2 of first stubble cane probably was due to the low number of stalks obtained per sample (six) as compared to the larger number obtained per sample (20) at other harvests.

Stalk weights among soil types at Harvest 3 of plant and stubble cane were of the order: Soil I > Soil II > Soil III. The weights from Soils I and III differed statistically in stubble cane and approached significance in plant cane. Other relationships of weights from plant and stubble cane to fertilizer treatments and soil types were either not significant or were not considered important.

Mean stalk length of plant and stubble cane at all harvests was generally of the order: L65-69 = CP52-68 > L62-96 > L60-25, but most of the

Table 16. — Mean stalk weight, length and diameter of plant cane at three harvest periods as related to variety, fertilizer treatment and soil type

	Harvest Period								
	1			2			3		
Variable	Wt	Length	Diam.	Wt	Length	Diam.	Wt	Length	Diam.
	Lb	In.	In.	Lb	In.	In.	Lb	In.	In.
CP 52-68	2.18	77.5	.95	2.44	95.1	.92	2.69	97.6	.95
L 60-25	2.03	73.5	1.01	2.27	85.7	1.00	2.44	88.2	.99
L 62-96	2.60	76.2	1.09	2.85	87.0	1.02	3.20	93.7	1.06
L 65-69	2.21	80.8	.98	2.44	94.6	.96	2.69	98.6	.97
LSD .05	.14	3.6	.05	.15	4.1	.03	.16	4.0	.03
80-0-0	2.28	78.2	1.00	2.53	93.9	.99	2.81	97.1	1.00
80-0-80	2.24	76.3	1.01	2.47	90.6	.97	2.76	94.6	.99
160-0-0	2.27	78.5	1.01	2.53	90.9	.97	2.78	94.4	.99
160-0-80	2.20	75.1	1.00	2.47	87.0	.98	2.66	92.0	.98
LSD .05	NS	NS	NS	NS	4.1	NS	NS	4.0	NS
Soil I	2.25	80.0	1.01	2.51	91.7	.97	2.81	96.9	.99
Soil II	2.28	76.7	1.01	2.47	90.2	.97	2.78	95.9	.99
Soil III	2.21	74.3	1.00	2.53	89.9	.99	2.67	90.8	.99
LSD .05	NS	3.2	NS	NS	NS	NS	NS	3.5	NS

differences between L62-96 and L60-25 were not significant.

There was a trend for fertilizer K to decrease stalk length of plant cane (Table 16), and, as an average of the two levels of fertilizer N and the other variables, the effect was significant at Harvests 1 and 2. The trend did not exist in stubble cane (Table 17). There was also a trend in plant and stubble cane for stalk length to vary among soil types in the order: Soil I > Soil II > Soil III.

Generally, stalk diameter was highest from L62-96 and lowest from CP52-68, but the differences were relatively small in stubble cane. Relationships of diameter to fertilizer treatment and soil type in plant and stubble cane were generally small and not significant.

Correlations Among Yield and Stalk Data

Simple correlation coefficients among number of stalks of millable cane, cane yield, and stalk weight, length, and diameter at three harvest periods are presented in Table 18.

In plant cane, the number of millable stalks was significantly correlated with Yield 2, while in stubble cane, it was correlated with cane yield at each harvest. Number of stalks was negatively correlated with stalk weight in plant and stubble cane at all harvests. Number of stalks was negatively correlated with stalk diameter only at Harvests 1 and 3 of plant cane.

Except for the low correlation between Yield 2 and Length 2 in plant

Table 17. — Mean stalk weight, length, and diameter of first stubble at three harvest periods as related to variety, fertilizer treatment, and soil type

	Harvest Period								
	1			2			3		
Variable	Wt	Length	Diam.	Wt	Length	Diam.	Wt.	Length	Diam.
	Lb	In.	In.	Lb	In.	In.	Lb	In.	In.
CP 52-68	2.13	76.3	.94	2.50	83.1	.99	2.48	82.5	.95
L 60-25	1.94	70.9	.98	2.23	77.6	.98	2.20	76.6	.96
L 62-96	2.24	72.0	.99	2.58	78.5	1.01	2.61	78.5	1.00
L 65-69	2.14	76.7	.95	2.68	86.2	.99	2.49	83.7	.95
LSD .05	.10	2.4	.03	.18	2.9	NS	.13	2.5	.03
120-0-0	2.11	74.5	.95	2.52	81.4	1.00	2.41	80.2	.96
120-0-80	2.12	73.8	.97	2.43	80.8	.98	2.49	80.9	.96
240-0-0	2.06	73.5	.95	2.52	81.6	.99	2.42	79.8	.98
240-0-80	2.17	74.0	.98	2.53	81.6	1.00	2.46	80.4	.97
LSD .05	.10	NS	.03	NS	NS	NS	NS	NS	NS
Soil I	2.12	74.7	.94	2.55	84.0	.98	2.57	84.4	.96
Soil II	2.11	73.9	.95	2.54	81.8	1.00	2.41	80.0	.96
Soil III	2.12	73.2	.99	2.41	78.3	1.00	2.36	76.6	.98
LSD .05	NS	NS	.03	NS	2.5	NS	.11	2.1	NS

Table 18. — Correlation coefficients (r)[1] among the number of stalks of millable cane, cane yield, and stalk weight, length and diameter at three harvest periods[2]

	Yield 1	Yield 2	Yield 3	Wt 1	Wt 2	Wt 3	Length 1	Length 2	Length 3	Diam. 1	Diam. 2	Diam. 3
						Plant Cane						
No. of stalks	.282	.312	.223	-.726	-.661	-.688	-.228	-.199	-.198	-.494	-.066	-.419
Yield 1		.401	.639	.445	.076	.234	.342	-.127	.188	.319	.197	.134
Yield 2			.545	.004	.499	.136	-.188	.028	.095	.030	.529	.166
Yield 3				.251	.238	.545	.099	-.069	.443	.174	.256	.401
Wt 1					.681	.816	.444	.075	.299	.714	.227	.532
Wt 2						.748	.054	.172	.240	.502	.506	.547
Wt 3							.246	.085	.470	.582	.284	.702
Length 1								.445	.555	.019	-.352	-.135
Length 2									.669	-.377	-.378	-.310
Length 3										-.180	-.295	.024
Diam. 1											.485	.633
Diam. 2												.634
						First Stubble Cane						
No. of stalks	.780	.616	.713	-.427	-.409	-.427	-.127	.015	-.043	.128	-.207	-.202
Yield 1		.679	.818	.228	-.101	.008	.209	.240	.175	.397	-.073	-.017
Yield 2			.734	.007	.462	.101	.350	.598	.439	.046	.289	-.081
Yield 3				.082	.042	.326	.263	.402	.482	.093	-.103	.042
Wt 1					.479	.693	.479	.301	.307	.401	.216	.319
Wt 2						.592	.533	.676	.545	-.083	.568	.157
Wt 3							.490	.477	.656	-.017	.148	.362
Length 1								.736	.772	-.213	-.045	-.236
Length 2									.792	-.324	-.018	-.186
Length 3										-.456	-.116	-.247
Diam. 1											.328	.460
Diam. 2												.400

1/ Least significant r at 1% level = .369. Least significant r at 5% level = .285.

2/ The number of stalks was determined only at the first harvest and the other variables were determined at each of the three harvest periods. The designations, 1, 2 and 3 refer to yield and yield-component data obtained at Harvests 1, 2 and 3.

cane, which probably resulted from the relatively low number of stalks obtained per sample at Harvest 2, plant cane yields correlated significantly with all corresponding stalk weights, lengths, and diameters. A similar trend was noted in stubble cane. The exceptions in stubble cane were low correlations between Yield 1 and Weight 1, Yield 1 and Length 1, and Yield 3 and Diameter 3.

Except for the low correlation between Weight 2 and Length 2 in plant cane, plant and stubble cane weights correlated significantly with all corresponding stalk lengths and diameters.

Stalk length and diameter were negatively correlated at Harvest 2 of plant cane and negative correlations at Harvests 1 and 3 of stubble cane approached significance.

Juice Extraction and Lodging Rating

It was found that the percentage juice extraction from plant and stubble cane was not significantly related to variety, fertilizer treatment, or soil type.

Lodging ratings showed that most of the CP52-68 plant cane did not lodge and that only a relatively small amount of CP52-68 stubble cane lodged. Plant and stubble cane of other varieties lodged to a substantial degree. Degree of lodging was not significantly associated with fertilizer treatment or soil type in plant and stubble cane. The generally higher degree of stubble cane lodging was due partially to Hurricane Carmen, September 6-7, 1974.

Tops and Trash, Bagasse, and Juice Yields

Table 19 contains data showing mean yields of tops and trash, bagasse, and juice from plant and stubble cane as related to variety, fertilizer treatment, and soil type. Calculations with these data and macronutrient data in Tables 21 through 26 were made to determine macronutrient contents of above-ground parts of cane which are reported in Tables 21 through 26. Similar calculations with data in Table 19 and micronutrient data in Tables 31 through 34 were made to determine the micronutrient contents of above-ground parts of cane which are reported in Tables 31 through 34.

Differences among yields of cane components shown in Table 19 influenced nutrient content data, but the differences are considered less important, for purposes of this study, than differences among nutrient contents of cane, which are discussed later in detail.

Table 19. — Mean tops and trash[1], bagasse[1], and juice[2] yields of plant and first stubble cane as related to variety, fertilizer treatment, and soil type

	Plant Cane			First stubble Cane		
Variable	Tops&trash	Bagasse	Juice	Tops&trash	Bagasse	Juice
	Lb/A					
CP 52-68	5350	10639	39693	6510	13429	39381
L 60-25	5191	11145	41401	5770	14727	42055
L 62-96	5934	12232	41360	6525	13396	36141
L 65-69	6117	12498	43885	7696	15662	43737
LSD .05	440	1048	NS	513	1175	3558
N1-0-0[3]	5571	11151	40469	6395	13608	38198
N1-0-80	5427	11844	41912	6575	14304	39629
N2-0-0	5534	11656	41295	6583	14412	39916
N2-0-80	6061	11864	42662	6949	14891	43573
LSD .05	440	NS	NS	513	1175	3558
Soil I	6032	11628	42146	6737	14884	41647
Soil II	5358	11421	41549	6559	14445	40689
Soil III	5555	11837	41059	6580	13582	38651
LSD .05	382	NS	NS	NS	1018	NS

[1] Dry matter basis.

[2] Wet basis.

[3] N1 = 80 lb of N/A for plant and 120 lb/A for first stubble cane.
N2 = 160 lb of N/A for plant and 240 lb/A for first stubble cane.

Macronutrient Contents of Leaf Blades

The N content of leaf blades from CP52-68 plant and stubble cane (Table 20) was significantly lower than the N content of the other varieties. In stubble cane the N content of L62-96 was significantly higher than the N content of L60-25 and L65-69. The N content of plant cane leaf blades from the 160-0-0 treatment was significantly higher than from the 80-0-0 treat-

Table 20. — Mean macronutrient content of leaf blades as related to variety, fertilizer treatment, and soil type

Variable	Macronutrient content					
	N	S	P	K	Ca	Mg
	- - - - - - - -	- - - - - - - -	- - - - - - - -	% - - - - - - - -	- - - - - - - -	- - - - - - - -
			Plant Cane			
CP 52-68	1.53	.146	.157	1.43	.290	.144
L 60-25	1.63	.146	.157	1.50	.256	.179
L 62-96	1.60	.150	.199	1.61	.300	.136
L 65-69	1.60	.140	.191	1.61	.280	.155
LSD .05	.04	NS	.005	.09	.012	.009
80-0-0	1.57	.145	.178	1.45	.287	.158
80-0-80	1.58	.147	.176	1.58	.280	.151
160-0-0	1.61	.151	.174	1.51	.276	.153
160-0-80	1.60	.138	.176	1.61	.283	.153
LSD .05	.04	NS	NS	.09	NS	NS
Soil I	1.59	.159	.178	1.54	.292	.164
Soil II	1.57	.135	.172	1.44	.280	.156
Soil III	1.59	.142	.178	1.64	.273	.141
LSD .05	NS	.013	.005	.08	.011	.008
			First Stubble Cane			
CP 52-68	1.47	.119	.175	1.08	.334	.168
L 60-25	1.62	.124	.175	1.22	.261	.198
L 62-96	1.69	.131	.219	1.36	.329	.157
L 65-69	1.60	.113	.218	1.27	.269	.167
LSD .05	.05	.013	.010	.11	.018	.010
120-0-0	1.59	.122	.204	1.11	.301	.178
120-0-80	1.59	.124	.198	1.33	.287	.163
240-0-0	1.59	.122	.194	1.13	.312	.181
240-0-80	1.62	.120	.192	1.35	.292	.168
LSD .05	NS	NS	.010	.11	.018	.010
Soil I	1.64	.136	.204	1.22	.302	.181
Soil II	1.57	.117	.196	1.23	.302	.173
Soil III	1.58	.112	.190	1.24	.290	.164
LSD .05	.04	.011	.008	NS	NS	.009

ment. Differences in N content of leaf blades among fertilizer treatments of stubble cane were not significant. The N content of stubble cane leaf blades from Soil I was higher than from Soils II and III.

Leaf S was not significantly related to varieties in plant cane, nor was it related to fertilizer treatments in plant and stubble cane. In stubble cane, leaf S was significantly higher in L62-96 than in L65-69. In plant and stubble cane, leaf S was statistically of the order: Soil I> Soil II = Soil III.

The leaf-blade P contents from CP52-68 and L60-25 plant and stubble cane were substantially lower than from L62-96 and L65-69. Leaf-blade P contents were not influenced by fertilizer treatments in plant cane. The influence of fertilizers on P in stubble cane was not considered important due to the relatively high contents, compared with plant cane, and generally high levels of leaf-blade P in both plant and stubble cane (*14, 19*). Leaf-blade P content from plant cane on Soil II was significantly lower than from cane on Soils I and III. In stubble cane, leaf P was of the order: Soil I > Soil II > Soil III, and the differences between Soils I and II, and between Soils I and III were significant.

Leaf K contents from CP52-68 and L60-25 plant cane were significantly lower than from L62-96 and L65-69. In stubble cane, leaf K was of the order: L62-96 > L65-69 > L60-25 > CP52-68, but the differences between L62-96 and L65-69, and between L65-69 and L60-25, were not significant.

Fertilizer N, as an average of all other variables, resulted in no significant effect on leaf K of plant and stubble cane. Fertilizer K, as an average of all other variables, resulted in increases of K in plant and stubble cane leaf blades at both levels of N. In plant cane, leaf K was of the order: Soil III> Soil I> Soil II, and in stubble cane, differences in leaf K among soil types were not significant.

Since Ca and Mg contents of leaf blades were substantially higher than levels considered to be critically low for nutrition of sugarcane in Louisiana (*17*), differences noted among variables were apparently of little consequence.

Macronutrient Contents of Above-Ground Parts

Calculations with data showing macronutrient contents of tops and trash, bagasse, and juice from Tables 21 through 26 and appropriate yields in Table 19 resulted in values shown in Tables 21 through 26. Values for macronutrient contents of millable cane are in pounds per acre and pounds per ton, and values for macronutrient contents of above-ground parts are in pounds per acre and pounds per ton of millable cane.

Nitrogen. — In plant cane (Table 21), L60-25 contained significantly more N in each ton of millable cane than CP52-68 and L62-96, but differences among varieties in stubble cane were not significant. The N contents of millable cane and of above-ground parts differed significantly among varieties in pounds per acre, partially due to differences in yield, but the N contents of above-ground parts were not significantly different among varieties in pounds per ton of millable cane.

For N contents of plant parts, the effect of the higher rate of fertilizer N,

Table 21. — Mean nitrogen contents of above-ground parts as related to variety, fertilizer treatment, and soil type

	Nitrogen Content						
Variable	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - - % - - - - - - -			Lb/A	Lb/T	Lb/A	Lb/T MC
			Plant Cane				
CP 52-68	.88	.34	.070	63.2	1.87	111.4	3.27
L 60-25	.86	.37	.073	71.9	2.04	116.3	3.30
L 62-96	.90	.31	.067	65.5	1.80	118.7	3.27
L 65-69	.85	.34	.070	72.6	1.96	124.7	3.37
LSD .05	NS	.03	NS	6.4	.14	8.3	NS
80-0-0	.86	.32	.062	60.5	1.77	108.3	3.17
80-0-80	.86	.32	.063	64.0	1.78	111.4	3.10
160-0-0	.90	.35	.076	72.0	2.03	122.0	3.43
160-0-80	.87	.36	.080	76.7	2.08	129.3	3.52
LSD .05	NS	.03	.008	6.4	.14	8.3	.16
Soil I	.91	.35	.066	67.9	1.90	122.8	3.43
Soil II	.87	.34	.066	66.3	1.87	114.0	3.22
Soil III	.82	.33	.078	70.7	1.98	116.5	3.26
LSD .05	.05	NS	.007	NS	NS	7.2	.14
			First Stubble Cane				
CP 52-68	.70	.36	.065	74.6	1.99	120.2	3.23
L 60-25	.77	.38	.063	83.2	2.10	127.6	3.21
L 62-96	.76	.34	.065	69.2	1.98	119.0	3.41
L 65-69	.74	.35	.058	82.0	1.98	138.9	3.36
LSD .05	.06	.03	NS	8.6	NS	10.4	NS
120-0-0	.71	.34	.053	67.6	1.86	112.6	3.12
120-0-80	.71	.31	.053	66.0	1.74	112.7	2.98
240-0-0	.78	.39	.074	86.6	2.27	138.1	3.64
240-0-80	.77	.39	.071	88.8	2.17	142.3	3.47
LSD .05	NS	.03	.009	8.6	.18	10.4	.22
Soil I	.81	.39	.070	88.0	2.23	143.0	3.63
Soil II	.74	.35	.060	75.6	1.95	123.9	3.21
Soil III	.67	.33	.059	68.2	1.85	112.5	3.07
LSD .05	.05	.03	.008	7.5	.16	9.0	.19

160 pounds per acre in plant cane, when compared with the 80-pounds-per-acre rate, and 240 pounds per acre in stubble cane, when compared with the 120-pound-per-acre rate, with or without fertilizer K, was positive and generally statistically significant.

As an average of fertilizer N treatments and all other variables, fertilizer K applied to stubble cane resulted in some decrease in the N content of above-ground parts in pounds per ton of millable cane. The F-value was 4.07 and the required F-value for significance at the 5 percent level of probability was 4.17.

Table 22. — Mean sulphur contents of above-ground parts as related to variety, fertilizer treatment, and soil type

	Sulphur content						
Variable	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - - % - - - - - - -			Lb/A	Lb/T	Lb/A	Lb/T MC
			Plant Cane				
CP 52-68	.117	.051	.0145	11.28	.33	17.55	.52
L 60-25	.098	.048	.0148	11.29	.32	16.56	.47
L 62-96	.111	.035	.0118	9.09	.25	15.64	.43
L 65-69	.092	.041	.0127	16.27	.29	16.33	.44
LSD .05	.013	.007	NS	1.92	.05	NS	NS
80-0-0	.114	.046	.0128	10.28	.30	16.61	.49
80-0-80	.096	.042	.0137	10.81	.30	15.89	.44
160-0-0	.114	.046	.0137	11.01	.31	17.27	.49
160-0-80	.093	.042	.0136	10.65	.29	16.29	.44
LSD .05	.013	NS	NS	NS	NS	NS	NS
Soil I	.108	.050	.0149	12.20	.34	18.48	.52
Soil II	.107	.042	.0132	10.27	.29	15.95	.45
Soil III	.099	.039	.0123	9.63	.27	15.12	.43
LSD .05	NS	.006	NS	1.76	.05	2.12	.06
			First Stubble Cane				
CP 52-68	.085	.037	.0043	6.70	.18	12.20	.33
L 60-25	.085	.032	.0046	6.73	.17	11.52	.29
L 62-96	.088	.031	.0039	5.63	.16	11.32	.33
L 65-69	.074	.030	.0037	6.29	.15	11.92	.29
LSD .05	NS	NS	.0008	NS	NS	NS	NS
120-0-0	.085	.031	.0043	5.86	.16	11.32	.31
120-0-80	.083	.036	.0048	7.11	.19	12.55	.33
240-0-0	.087	.034	.0038	6.49	.17	11.96	.32
240-0-80	.077	.029	.0036	5.85	.14	11.13	.27
LSD .05	NS	NS	.0008	NS	NS	NS	NS
Soil I	.089	.033	.0049	6.97	.18	12.83	.33
Soil II	.079	.031	.0035	5.91	.15	10.96	.29
Soil III	.082	.034	.0040	6.16	.17	11.42	.32
LSD .05	NS	NS	.0007	NS	NS	1.16	NS

In plant and stubble cane, the N content of above-ground parts in pounds per ton of millable cane was statistically of the order: Soil I> Soil II = Soil III.

Sulphur. — No general relationship was noted in plant and stubble cane among S contents of plant parts and varieties or fertilizer treatments (Table 22).

In plant cane, there was a tendency for S contents to vary in the order: Soil I> Soil II> Soil III, but in stubble cane a similar tendency did not exist.

Table 23. — Mean phosphorus contents of above-ground parts as related to variety, fertilizer treatment, and soil type

	Phosphorus content						
Variable	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - -	% - - - - -	- -	Lb/A	Lb/T	Lb/A	Lb/T MC
			Plant Cane				
CP 52-68	.105	.060	.0145	12.17	.36	17.81	.52
L 60-25	.099	.056	.0126	11.47	.33	16.62	.47
L 62-96	.123	.060	.0150	13.54	.37	20.80	.57
L 65-69	.131	.076	.0213	18.88	.51	26.89	.73
LSD .05	.007	.005	.0020	1.72	.05	2.11	.06
80-0-0	.117	.062	.0158	13.36	.39	19.95	.58
80-0-80	.114	.068	.0174	15.48	.43	21.69	.60
160-0-0	.117	.061	.0156	13.62	.38	20.09	.56
160-0-80	.111	.062	.0147	13.61	.37	20.40	.55
LSD .05	NS	.005	.0020	1.72	.05	NS	NS
Soil I	.115	.061	.0146	13.29	.37	20.28	.56
Soil II	.118	.066	.0165	14.40	.41	20.72	.58
Soil III	.111	.063	.0165	14.36	.40	20.60	.57
LSD .05	.006	NS	.0018	NS	NS	NS	NS
			First Stubble Cane				
CP 52-68	.105	.084	.0211	19.60	.53	26.44	.71
L 60-25	.114	.084	.0208	21.06	.53	27.60	.69
L 62-96	.131	.076	.0204	17.33	.51	25.85	.75
L 65-69	.148	.095	.0259	26.30	.64	37.74	.92
LSD .05	.010	.008	.0024	2.49	.05	2.72	.06
120-0-0	.130	.084	.0222	19.81	.55	28.22	.79
120-0-80	.125	.089	.0247	22.32	.60	30.51	.82
240-0-0	.123	.084	.0204	20.63	.53	28.79	.74
240-0-80	.121	.083	.0209	21.52	.53	30.10	.73
LSD .05	NS	NS	.0024	2.49	.05	NS	.06
Soil I	.128	.077	.0186	19.33	.49	28.09	.71
Soil II	.124	.090	.0240	22.75	.59	30.98	.80
Soil III	.121	.087	.0236	21.14	.57	29.15	.79
LSD .05	NS	.007	.0022	2.16	.05	2.36	.05

Phosphorus. — In plant and stubble cane, the P contents of plant parts shown in Table 23 were significantly higher from L65-69 than from the other varieties.

When compared with other varieties, the combination of higher tops and trash yields from L65-69 plant and stubble cane and higher P contents of the tops and trash indicate a higher amount of P remaining in the field following harvest of L65-69, but the higher bagasse and juice yields and higher P contents of the bagasse and juice from L65-69 show that more P was also removed from the field in millable cane. Although a comparison of data from all varieties showed that more P in tops and trash from L65-69 remained in the field following harvest, the comparison showed a greater absolute difference in amounts removed from the field in millable cane. Therefore, the principal concern for P nutrition of L65-69 may be application of fertilizer P to the variety when grown on soils normally considered adequate in P status, or application of a higher rate than normal on soils considered to require fertilizer P.

The relatively high amount of P in juice from L65-69 plant and stubble cane when compared with the other varieties may contribute to better juice clarification in milling operations.

The relationships of fertilizer treatments and soil types to the amounts of P in the plant parts were either not significant or not considered important.

The P contents of millable cane in pounds per ton and in above-ground parts in pounds per ton of millable cane, particularly in stubble cane, were generally higher than P contents normally found from cane grown on Mississippi terrace soils (*16, 21*).

Potassium. — Among varieties in plant and stubble cane (Table 24), K contents of above-ground parts per ton of millable cane showed no consistent trend. As an example, L62-96 contained significantly more K than L60-25 in plant cane, while the other varieties contained intermediate amounts, but L62-96 contained significantly less K than L65-69 in stubble cane, while the other varieties contained intermediate amounts.

In plant and stubble cane the effect of fertilizer K on the K content of millable cane in pounds per ton and on above-ground parts in pounds per ton of millable cane was of the order: N1-0-80> N1-0-0 and N2-0-80>

Table 24. — Mean potassium contents of above-ground parts as related to variety, fertilizer treatment, and soil type

	Potassium content						
Variable	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - - % - - - - - - -			Lb/A	Lb/T	Lb/A	Lb/T MC
			Plant Cane				
CP 52-68	1.21	.43	.151	105.7	3.10	170.3	5.01
L 60-25	1.21	.35	.120	88.4	2.51	151.1	4.29
L 62-96	1.38	.40	.134	104.2	2.86	186.0	5.12
L 65-69	1.28	.33	.137	101.9	2.74	183.9	4.84
LSD .05	.10	.05	.023	15.5	.41	20.4	.57
80-0-0	1.23	.33	.111	81.3	2.37	154.2	4.37
80-0-80	1.31	.43	.162	119.4	3.31	190.7	5.29
160-0-0	1.25	.34	.118	87.8	2.48	157.0	4.43
160-0-80	1.29	.40	.152	111.6	3.05	189.5	5.16
LSD .05	NS	.05	.023	15.5	.41	20.4	.57
Soil I	1.21	.34	.122	91.7	2.53	166.6	4.56
Soil II	1.31	.38	.134	98.8	2.81	169.9	4.81
Soil III	1.29	.40	.150	109.6	3.06	182.0	5.07
LSD .05	.09	.05	.020	13.4	.35	NS	NS
			First Stubble Cane				
CP 52-68	1.06	.41	.156	116.4	3.11	185.2	4.98
L 60-25	1.20	.34	.141	109.9	2.74	178.4	4.46
L 62-96	1.06	.29	.107	75.9	2.24	144.8	4.24
L 65-69	1.25	.36	.155	123.3	3.02	220.2	5.39
LSD .05	.14	.05	.025	19.4	.45	23.9	.57
120-0-0	1.15	.31	.116	86.0	2.38	158.7	4.41
120-0-80	1.15	.41	.172	125.5	3.35	201.4	5.38
240-0-0	1.13	.31	.118	93.3	2.41	167.8	4.37
240-0-80	1.15	.37	.153	120.7	2.96	200.8	4.92
LSD .05	NS	.05	.025	19.4	.45	23.9	.57
Soil I	1.17	.28	.115	90.2	2.26	169.7	4.26
Soil II	1.09	.36	.141	109.4	2.85	180.8	4.71
Soil III	1.17	.41	.163	119.5	3.23	196.0	5.33
LSD .05	NS	.05	.022	16.8	.39	20.7	.49

N2-0-0. Comparisons of fertilizer treatments N1-0-0 with N2-0-0 and N1-0-80 with N2-0-80 showed that fertilizer N had no significant effect on K content of the cane.

Although some differences were not statistically significant, the K contents of millable cane in pounds per acre and pounds per ton and in above-ground parts in pounds per acre and pounds per ton of millable cane were of the order: Soil III> Soil II> Soil I in plant and stubble cane.

Calcium. — In plant cane (Table 25), Ca content of above-ground parts per ton of millable cane was statistically of the order: L62-96 = L65-69 =

Table 25. — Mean calcium contents of above-ground parts as related to variety, fertilizer treatment, and soil type

	Calcium content						
Variable	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - - % - - - - - - -			Lb/A	Lb/T	Lb/A	Lb/T MC
				Plant Cane			
CP 52-68	.319	.034	.0107	7.87	.23	24.94	.73
L 60-25	.264	.033	.0101	7.82	.22	21.52	.61
L 62-96	.309	.036	.0116	9.21	.25	27.54	.76
L 65-69	.269	.037	.0153	11.36	.31	27.82	.75
LSD .05	.028	.004	.0013	1.01	.03	2.31	.06
80-0-0	.292	.034	.0116	8.53	.25	24.82	.72
80-0-80	.284	.034	.0116	8.92	.25	24.29	.68
160-0-0	.294	.036	.0124	9.35	.26	25.62	.72
160-0-80	.290	.036	.0120	9.47	.25	27.08	.73
LSD .05	NS	NS	NS	NS	NS	NS	NS
Soil I	.288	.037	.0122	9.43	.26	26.78	.75
Soil II	.290	.033	.0125	9.10	.25	24.61	.70
Soil III	.292	.035	.0110	8.66	.24	24.98	.70
LSD .05	NS	.003	.0012	NS	NS	2.00	.05
				First Stubble Cane			
CP 52-68	.350	.044	.0117	10.49	.28	33.30	.90
L 60-25	.295	.042	.0114	10.97	.27	27.99	.71
L 62-96	.396	.054	.0151	12.76	.37	38.63	1.12
L 65-69	.293	.049	.0160	14.69	.36	37.31	.91
LSD .05	.033	.006	.0015	1.33	.04	3.99	.11
120-0-0	.325	.045	.0125	10.90	.30	31.62	.88
120-0-80	.325	.044	.0132	11.54	.30	32.89	.88
240-0-0	.342	.051	.0142	13.19	.34	35.79	.95
240-0-80	.341	.048	.0142	13.27	.32	36.92	.91
LSD .05	NS	.006	.0015	1.33	.04	3.99	NS
Soil I	.344	.050	.0153	13.82	.35	36.99	.94
Soil II	.336	.048	.0133	12.37	.32	34.39	.90
Soil III	.320	.044	.0119	10.48	.29	31.54	.88
LSD .05	NS	.005	.0013	1.15	.03	3.46	NS

CP52-68 > L60-25 and in stubble cane was of the order: L62-96> L65-69 = CP52-68 > L60-25.

No important relationship was noted between Ca contents of plant parts and fertilizer treatments applied to plant and stubble cane, but there was a tendency for Ca contents of the plant parts to vary in the order: Soil I> Soil II> Soil III.

Magnesium. — In plant cane (Table 26), Mg content of above-ground parts per ton of millable cane was statistically of the order: L62-96 =

Table 26. — Mean magnesium contents of above-ground parts as related to variety, fertilizer treatment, and soil type

	Magnesium content						
Variable	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - -	% - - - - - -	-	Lb/A	Lb/T	Lb/A	Lb/T MC
			Plant Cane				
CP 52-68	.130	.035	.0129	8.60	.25	15.56	.46
L 60-25	.156	.043	.0141	10.60	.30	18.55	.53
L 62-96	.132	.047	.0155	12.11	.33	19.91	.55
L 65-69	.121	.142	.0175	12.93	.35	20.38	.55
LSD .05	.008	.004	.0018	1.13	.03	1.59	.04
80-0-0	.136	.042	.0149	10.45	.30	18.02	.52
80-0-80	.129	.040	.0143	10.77	.30	17.75	.50
160-0-0	.140	.044	.0154	11.39	.32	18.89	.53
160-0-80	.134	.043	.0153	11.65	.31	19.74	.54
LSD .05	.008	.004	NS	1.13	NS	1.59	.04
Soil I	.137	.045	.0161	11.93	.33	20.19	.56
Soil II	.136	.041	.0150	10.69	.30	17.82	.50
Soil III	.131	.040	.0139	10.57	.29	17.79	.50
LSD .05	NS	.003	.0016	1.01	.03	1.38	.04
			First Stubble Cane				
CP 52-68	.149	.047	.0144	12.07	.32	21.81	.59
L 60-25	.168	.051	.0152	13.82	.35	23.54	.59
L 62-96	.169	.064	.0177	15.02	.43	26.13	.75
L 65-69	.138	.051	.0170	15.63	.38	26.27	.64
LSD .05	.013	.005	.0010	1.44	.04	2.63	.06
120-0-0	.151	.052	.0154	12.94	.36	22.51	.63
120-0-80	.143	.048	.0154	12.98	.34	22.33	.59
240-0-0	.173	.059	.0168	15.15	.40	26.50	.70
240-0-80	.157	.055	.0168	15.47	.38	26.41	.65
LSD .05	.013	.005	.0010	1.44	.04	2.63	.06
Soil I	.170	.059	.0178	16.28	.42	27.67	.71
Soil II	.156	.053	.0159	14.17	.37	24.35	.63
Soil III	.143	.047	.0144	11.95	.33	21.29	.59
LSD .05	.011	.005	.0009	1.25	.03	2.28	.06

Table 27. — Correlation coefficients (r)[1] among topsoil pH, macronutrients in topsoil, and macronutrient contents of above-ground (AG) parts[2]

	Total N3/	AG N	"Soil" S	Ext. S	AG S	Ext. P	AG P	Ext. K	AG K	Ext. Ca	AG Ca	Ext. Mg	AG Mg
						Plant Cane							
Topsoil pH	.568	-.140	.702	.652	-.323	.138	.235	.596	.184	.802	.056	.410	-.292
Total N3/		-.179	.659	.563	-.156	.255	.114	.433	.116	.614	-.209	.284	-.289
AG N			.002	-.074	.412	.002	.028	-.290	-.053	-.224	.448	-.448	.525
"Soil" S				.671	-.085	.083	.309	.468	.155	.606	-.009	.310	-.189
Ext. S					-.228	.185	.375	.430	.265	.650	.080	.214	-.127
AG S						.220	-.123	-.656	-.282	-.498	.345	-.677	.168
Ext. P							.311	-.214	-.197	-.050	.279	-.158	.099
AG P								.028	.227	.056	.371	-.030	.260
Ext. K									.512	.862	-.332	.865	-.454
AG K										.373	-.020	.331	-.356
Ext. Ca											-.246	.671	-.493
AG Ca												-.478	.528
Ext. Mg													-.445
						First Stubble Cane							
Topsoil pH	.568	-.389	.702	.652	-.197	.138	.522	.596	.442	.802	.042	.410	-.301
Total N3/		-.364	.659	.563	.108	.255	.206	.433	.331	.614	-.083	.284	-.283
AG N			-.225	-.407	.167	.177	-.299	-.508	-.443	-.548	.372	-.481	.724
"Soil" S				.671	-.056	.083	.569	.468	.386	.606	.032	.310	-.209
Ext. S					.010	.185	.546	.430	.503	.650	.004	.214	-.298
AG S						.214	-.101	-.222	-.035	-.123	.420	-.384	.324
Ext. P							.046	-.214	-.163	-.050	.216	-.158	.236
AG P								.326	.545	.394	.078	.209	-.156
Ext. K									.605	.862	-.208	.865	-.532
AG K										.618	-.273	.366	-.636
Ext. Ca											-.161	.671	-.520
AG Ca												-.318	.781
Ext. Mg													-.506

1/ Least significant r at 1% level = .369. Lease significant r at 5% level = .285.

2/ Above-ground parts in pounds or fractional part of a pound per ton of millable cane.

3/ Total N in topsoil.

L65-69 = L60-25 > CP52-68 and in stubble cane was of the order: L62-96> L65-69 = L60-25 = CP52-68.

In stubble cane Mg contents of millable cane was increased in pounds per acre and pounds per ton, and it was also increased in above-ground parts in pounds per acre and pounds per ton of millable cane due to the higher level of fertilizer N. A similar trend occurred in plant cane, but the differences were not generally supported statistically.

There was a tendency for Mg contents of plant parts to vary in the order: Soil I> Soil II> Soil III, but the trend was stronger in stubble cane.

Correlations Among Topsoil pH and Macronutrient Contents of Topsoil, Leaf Blades, and Above-Ground Parts

Correlation coefficients among topsoil pH and macronutrient contents of topsoil, leaf blades, and above-ground parts are contained in Tables 27 through 29. With the exceptions of correlations discussed below under topsoil pH and macronutrient headings and correlations among topsoil pH and macronutrients, which were discussed previously (Table 3), the other relationships were considered to show no trends which provide practical information related to macronutrition of sugarcane in Louisiana.

Topsoil pH. — In plant cane (Tables 27 and 28), topsoil pH was negatively correlated with above-ground and leaf-blade S and Mg to a significant or highly significant degree. The correlation coefficients between topsoil pH and above-ground and leaf-blade S were r = -0.323 and r = -0.380, respectively, and between topsoil pH and above-ground and leaf-blade Mg were r = -0.292 and r = -0.364, respectively.

In stubble cane (Table 27), relationships between topsoil pH and above-ground N, P, K, and Mg were significant or highly significant (r = -0.389, r = 0.522, r = 0.442 and r = -0.301, respectively). The correlations between topsoil pH and leaf-blade S and Mg (Table 28) were highly significant (r = -0.598 and r = -0.372, respectively).

Nitrogen. — There was a tendency for the total N content of topsoil to correlate negatively with above-ground (AG) N in cane in pounds per ton of millable cane and with leaf-blade N (Tables 27 and 28). In Table 27 it may be seen that the relationship between topsoil N and above-ground N was significant in stubble cane (r = -0.364). In Table 29, it may be noted that above-ground N and leaf-blade N were significantly correlated in stubble cane (r = 0.333).

Sulphur. — "Soil" S and extractable S were not significantly associated with above-ground S in plant or stubble cane (Table 27). "Soil" S and leaf-blade S in stubble cane (Table 28) were negatively related (r= -0.447). It can be seen in Table 29 that correlations between leaf-blade S and above-ground S in plant and stubble cane were highly significant (r= 0.676 and r = 0.482, respectively).

Table 28. Correlation coefficients (r)[1] among topsoil pH, macronutrients in topsoil, and macronutrient contents of leaf blades (LB)

	Total N[2]	LB N	"Soil" S	Ext. S	LB S	Ext. P	LB P	Ext. K	LB K	Ext. Ca	LB Ca	Ext. Mg	LB Mg
Plant Cane													
Topsoil pH	.568	-.077	.702	.652	-.380	.138	.112	.596	.160	.802	-.143	.410	-.364
Total N[2]		-.011	.659	.563	-.175	.255	-.001	.433	.109	.614	-.283	.284	-.260
LB N			.065	.004	.227	-.114	.189	-.129	.381	-.047	-.139	-.190	.254
"Soil" S				.671	-.223	.083	.189	.468	.107	.606	-.100	.310	-.255
Ext. S					-.276	.185	.254	.430	.290	.650	-.074	.214	-.382
LB S						.221	.089	-.617	-.054	-.497	.435	-.713	.300
Ext. P							-.020	-.214	-.145	-.050	.208	-.158	.003
LB P								-.038	.540	-.047	.414	-.160	-.395
Ext. K									.324	.862	-.401	.865	-.478
LB K										.268	-.020	.061	-.394
Ext. Ca											-.349	.671	-.464
LB Ca												-.508	-.256
Ext. Mg													-.295
First Stubble Cane													
Topsoil pH	.568	-.218	.702	.652	-.598	.138	-.074	.596	.130	.802	-.059	.410	-.372
Total N[2]		-.151	.659	.563	-.407	.255	-.147	.433	.021	.614	-.005	.284	-.202
LB N			-.134	-.119	.461	-.105	.516	-.290	.443	-.283	-.089	-.336	.062
"Soil" S				.671	-.447	.083	.027	.468	.179	.606	-.028	.310	-.382
Ext. S					-.244	.185	.157	.430	.128	.650	-.085	.214	-.422
LB S						.007	.182	-.594	.081	-.557	.326	-.583	.191
Ext. P							.130	-.214	-.196	-.050	.283	-.158	.134
LB P								-.200	.407	-.234	.044	-.257	-.265
Ext. K									.310	.862	-.272	.865	-.457
LB K										.159	-.239	.119	-.377
Ext. Ca											-.180	.671	-.413
LB Ca												-.321	-.182
Ext. Mg													-.245

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[1] Least significant r at 1% level = .369. Least significant r at 5% level = .285.

[2] Total N in topsoil.

Table 29. — Correlation coefficients (r)[1] among macronutrients in above-ground (AG) parts[2] and leaf blades (LB)

	LB N	AG S	LB S	AG P	LB P	AG K	LB K	AG Ca	LB Ca	AG Mg	LB Mg
					Plant Cane						
AG N	.217	.412	.323	.028	.046	-.053	.150	.448	.078	.525	.169
LB N		-.063	.227	-.109	.189	-.059	.381	-.232	-.139	.235	.254
AG S			.676	-.123	-.250	-.282	-.454	.345	.342	.168	.382
LB S				-.070	.089	-.293	-.054	.333	.435	.374	.300
AG P					.613	.227	.265	.371	.218	.260	-.159
LB P						.219	.540	.450	.414	.423	-.395
AG K							.479	-.020	.080	-.356	-.548
LB K								.001	-.020	.102	-.394
AG Ca									.621	.528	-.214
LB Ca										.144	-.256
AG Mg											.366
					First Stubble Cane						
AG N	.333	.167	.344	-.299	.241	-.443	.024	.372	.230	.724	.226
LB N		.052	.461	.001	.516	-.273	.443	.286	-.089	.533	.062
AG S			.482	-.101	.128	-.035	-.057	.420	.399	.324	-.041
LB S				-.401	.182	-.414	.081	.303	.326	.494	.191
AG P					.446	.545	.216	.078	-.276	-.156	-.320
LB P						-.074	.407	.508	.044	.505	-.265
AG K							.268	-.273	-.244	-.636	-.402
LB K								.121	-.239	.109	-.377
AG Ca									.548	.781	-.398
LB Ca										.361	-.182
AG Mg											.053

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[1] Least significant r at 1% level = .369. Least significant r at 5% level = .285.

[2] Above-ground parts in pounds or fractional part of a pound per ton of millable cane.

Phosphorus. — The correlation between extractable P and above-ground P in plant cane, r = 0.311, was significant, but it was not significant in stubble cane (Table 27). Extractable P and leaf-blade P were not correlated significantly in plant or stubble cane (Table 28), but correlations between leaf-blade P and above-ground P in plant and stubble cane (r= 0.613 and r = 0.446, respectively) were highly significant (Table 29).

Potassium. — Correlations among extractable K, leaf-blade K, and above-ground K in plant and stubble cane were positive and were generally statistically significant or highly significant (Tables 27 through 29).

Calcium. — In plant cane, the negative relationship between extractable Ca and above-ground Ca (r= -0.246) approached significance (Table 27), and the negative relationship between extractable Ca and leaf-blade Ca (r = -0.349) was significant (Table 28). Although negative, similar relationships were not significant in stubble cane. The correlations between leaf-blade Ca and above-ground Ca in plant and stubble cane (r= 0.621 and r = 0.548, respectively) were highly significant (Table 29).

Magnesium. — In plant and stubble cane, the negative associations between extractable Mg and above-ground Mg (r = -0.445 and r =-0.506, respectively) were highly significant (Table 27). The negative association between extractable Mg and leaf-blade Mg (r = -0.295) was significant in

Table 30. — Mean micronutrient contents of plant and first stubble cane leaf blades as related to variety, fertilizer treatment, and soil type

	Micronutrient content							
	Plant cane				First stubble cane			
Variable	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
	- - - - - - - - - - - - - - - ppm - - - - - - - - - - - - - - -							
CP 52-69	46	26	16	6	57	58	23	5
L 60-25	50	29	19	5	62	48	27	5
L 62-96	53	32	22	8	61	66	34	6
L 65-69	50	31	12	6	71	61	25	5
LSD .05	NS	NS	5	NS	NS	10	NS	1
N1-0-0[1]	52	25	18	7	62	57	26	5
N1-0-80	53	30	17	6	61	45	22	5
N2-0-0	50	30	16	6	61	70	27	5
N2-0-80	46	32	17	6	67	63	34	5
LSD .05	NS	NS	NS	NS	NS	10	NS	NS
Soil I	51	31	22	7	54	64	23	5
Soil II	48	24	15	6	61	56	27	5
Soil III	51	33	14	6	73	55	32	5
LSD .05	NS	8	5	NS	11	NS	NS	NS

[1] N1 = 80 lb of N/A for plant and 120 lb/A for first stubble cane.
N2 = 160 lb of N/A for plant and 240 lb/A for first stubble cane.

plant cane and approached significance (r = -0.245) in stubble cane (Table 28). Leaf-blade Mg and above-ground Mg were significantly correlated in plant cane (r = 0.366) but were not significantly correlated in stubble cane (Table 29).

Micronutrient Contents of Leaf Blades

Data in Table 30 show no general relationships among varieties, fertilizer treatments, and soil types, and the Fe, Mn, Zn, and Cu contents of leaf blades. There is no obvious explanation for the generally higher levels

Table 31. — Mean iron contents of above-ground parts as related to variety, fertilizer treatment, and soil type

Variable	Iron content						
	Tops&tr.	Bagasse	Juice	Millable cane (MC)		Above-ground parts	
	- - - - - ppm - - - - -			Lb/A	Lb/T	Lb/A	Lb/T MC
			Plant Cane				
CP 52-68	63	34	21	1.20	.035	1.54	.045
L 60-25	66	36	20	1.24	.035	1.59	.045
L 62-96	61	42	19	1.29	.036	1.66	.046
L 65-69	55	35	22	1.39	.038	1.73	.047
LSD .05	NS	NS	NS	NS	NS	NS	NS
80-0-0	65	34	19	1.15	.033	1.50	.044
80-0-80	60	35	21	1.28	.036	1.61	.045
160-0-0	60	38	20	1.25	.035	1.58	.045
160-0-80	61	41	23	1.46	.040	1.83	.050
LSD .05	NS	NS	NS	NS	NS	NS	NS
Soil I	78	39	24	1.44	.040	1.90	.053
Soil II	56	41	22	1.38	.039	1.68	.047
Soil III	50	32	16	1.04	.029	1.32	.037
LSD .05	12	NS	NS	NS	NS	.36	.011
			First Stubble Cane				
CP 52-68	107	80	15	1.64	.044	2.34	.064
L 60-25	105	64	18	1.69	.043	2.31	.058
L 62-96	106	88	19	1.86	.054	2.54	.074
L 65-69	98	71	21	1.97	.048	2.71	.067
LSD .05	NS	NS	NS	NS	NS	NS	NS
120-0-0	100	87	21	2.00	.056	2.64	.074
120-0-80	106	74	18	1.72	.047	2.40	.065
240-0-0	113	79	16	1.77	.047	2.51	.066
240-0-80	97	64	17	1.67	.040	2.34	.057
LSD .05	NS	NS	NS	NS	NS	NS	NS
Soil I	68	69	16	1.68	.043	2.15	.055
Soil II	127	84	21	2.07	.054	2.88	.075
Soil III	116	75	17	1.63	.046	2.41	.067
LSD .05	20	NS	NS	NS	NS	.45	.014

of Fe, Mn, and Zn in leaf blades from stubble cane compared with plant cane.

It may be noted from the leaf blade data and critical contents reported by Evans and Juang, Page 8, that Zn and Cu in plant cane and Cu in stubble cane may have approached critically low levels in the experiments. However, tests with Zn and Cu in Louisiana have failed to show any significant effect on cane and sugar yields or on micronutrient contents of leaf blades (*13*).

Table 32. — Mean manganese contents of above-ground parts as related to variety, fertilizer treatment, and soil type

Variable	Manganese content						
	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - - ppm - - - - -			Lb/A	Lb/T	Lb/A	Lb/T MC
			Plant Cane				
CP 52-68	51	9	1.0	.14	.0041	.40	.0121
L 60-25	49	9	.9	.14	.0038	.39	.0110
L 62-96	55	13	1.6	.22	.0060	.55	.0150
L 65-69	65	16	2.0	.29	.0078	.68	.0184
LSD .05	9	3	.3	.04	.0011	.09	.0024
80-0-0	61	12	1.4	.20	.0057	.54	.0157
80-0-80	55	11	1.4	.20	.0054	.50	.0136
160-0-0	56	12	1.4	.20	.0055	.51	.0143
160-0-80	47	11	1.3	.19	.0051	.48	.0128
LSD .05	9	NS	NS	NS	NS	NS	.0024
Soil I	52	12	1.3	.19	.0055	.51	.0143
Soil II	52	11	1.3	.18	.0051	.46	.0129
Soil III	60	12	1.5	.21	.0057	.54	.0151
LSD .05	8	NS	NS	NS	NS	NS	NS
			First Stubble Cane				
CP 52-68	56	10	1.1	.18	.0048	.55	.0147
L 60-25	50	10	1.1	.20	.0051	.49	.0122
L 62-96	74	17	1.8	.29	.0086	.77	.0227
L 65-69	76	19	2.2	.39	.0096	.98	.0239
LSD .05	12	5	.6	.09	.0022	.15	.0040
120-0-0	67	13	1.5	.24	.0067	.68	.0192
120-0-80	62	14	1.7	.26	.0072	.67	.0184
240-0-0	63	16	1.6	.31	.0078	.73	.0187
240-0-80	64	13	1.4	.25	.0063	.70	.0173
LSD .05	NS	NS	NS	NS	NS	NS	NS
Soil I	61	14	1.6	.28	.0071	.70	.0175
Soil II	57	13	1.4	.24	.0063	.62	.0165
Soil III	74	15	1.7	.27	.0076	.76	.0211
LSD .05	11	NS	NS	NS	NS	NS	.0034

Micronutrient Contents of Above-Ground Parts

Calculations were made with data showing micronutrient contents of tops and trash, bagasse, and juice from Tables 31 through 34 and appropriate yields of tops and trash, bagasse, and juice shown in Table 19. The values obtained for micronutrient contents of millable cane in pounds per acre and pounds per ton and above-ground parts in pounds per acre and pounds per ton of millable cane are shown in Table 31 through 34.

Table 33. — Mean zinc contents of above-ground parts as related to variety, fertilizer treatment, and soil type

	Zinc content						
Variable	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - - ppm	- - - - -		Lb/A	Lb/T	Lb/A	Lb/T MC
			Plant Cane				
CP 52-68	33	11	1.4	.17	.0051	.34	.0102
L 60-25	30	13	2.8	.26	.0074	.42	.0120
L 62-96	24	16	1.9	.28	.0075	.42	.0115
L 65-69	21	14	2.4	.28	.0076	.40	.0109
LSD .05	10	NS	.8	.07	.0017	NS	NS
80-0-0	28	14	2.3	.25	.0073	.40	.0117
80-0-80	31	14	1.9	.25	.0069	.42	.0116
160-0-0	24	13	2.0	.23	.0065	.37	.0104
160-0-80	25	13	2.4	.26	.0069	.41	.0110
LSD .05	NS	NS	NS	NS	NS	NS	NS
Soil I	35	15	2.0	.25	.0070	.46	.0129
Soil II	26	12	2.1	.22	.0063	.36	.0102
Soil III	19	14	2.3	.27	.0074	.37	.0104
LSD .05	8	NS	NS	NS	NS	.09	.0023
			First Stubble Cane				
CP 52-68	35	9	1.7	.18	.0049	.41	.0109
L 60-25	34	12	2.3	.27	.0068	.47	.0116
L 62-96	32	12	2.5	.25	.0070	.46	.0134
L 65-69	24	16	3.1	.38	.0093	.57	.0138
LSD .05	NS	5	.9	.09	.0021	.12	NS
120-0-0	31	11	2.4	.25	.0068	.44	.0122
120-0-80	29	12	2.5	.28	.0072	.46	.0122
240-0-0	33	13	2.3	.30	.0075	.52	.0132
240-0-80	32	11	2.3	.27	.0064	.49	.0122
LSD .05	NS	NS	NS	NS	NS	NS	NS
Soil I	27	14	2.8	.33	.0081	.51	.0128
Soil II	39	10	2.4	.25	.0065	.50	.0130
Soil III	28	12	2.0	.24	.0064	.42	.0115
LSD .05	8	NS	NS	.08	NS	NS	NS

Iron. — Data in Table 31 indicate that significant differences in Fe content of plant and stubble cane were not obtained among varieties and fertilizer treatments.

Although in plant cane Fe contents of plant parts were generally of the order: Soil > Soil II= Soil III, the tendency in stubble cane was of the order: Soil II > Soil III> Soil I.

Manganese. — In plant cane (Table 32), the Mn content of above-ground parts in pounds per ton of millable cane was statistically of the

Table 34. — Mean copper contents of above-ground parts as related to variety, fertilizer treatment, and soil type

	Copper content						
Variable	Tops&tr.	Bagasse	Juice	Millable cane(MC)		Above-ground parts	
	- - - - -	ppm	- - - - -	Lb/A	Lb/T	Lb/T	Lb/T MC
			Plant Cane				
CP 52-68	2.7	1.2	.8	.042	.0013	.057	.0017
L 60-25	2.7	1.0	.6	.035	.0010	.049	.0014
L 62-96	3.6	1.2	.7	.046	.0013	.068	.0019
L 65-69	3.1	1.3	.6	.042	.0011	.061	.0017
LSD .05	.6	NS	.2	.006	.0002	.009	.0003
80-0-0	3.1	1.3	.7	.042	.0013	.060	.0017
80-0-80	2.9	1.2	.6	.041	.0011	.057	.0016
160-0-0	3.0	1.2	.7	.041	.0012	.057	.0016
160-0-80	3.1	1.1	.7	.042	.0011	.061	.0017
LSD .05	NS	NS	NS	NS	.0002	NS	NS
Soil I	2.5	1.6	.7	.048	.0013	.063	.0018
Soil II	3.3	1.2	.6	.039	.0012	.057	.0016
Soil III	3.2	.8	.7	.037	.0010	.056	.0016
LSD .05	.5	.3	NS	.006	.0002	NS	NS
			First Stubble Cane				
CP 52-68	3.2	2.0	.6	.050	.0013	.071	.0019
L 60-25	2.8	1.5	.5	.042	.0010	.058	.0014
L 62-96	2.9	2.0	.7	.052	.0015	.071	.0020
L 65-69	3.0	1.4	.5	.045	.0011	.068	.0016
LSD .05	NS	NS	.2	NS	.0003	NS	.0004
120-0-0	3.0	1.8	.6	.047	.0013	.067	.0018
120-0-80	2.7	1.5	.5	.042	.0011	.059	.0016
240-0-0	3.3	1.8	.5	.049	.0013	.071	.0019
240-0-80	2.9	1.7	.6	.050	.0012	.070	.0017
LSD .05	NS	NS	NS	NS	NS	NS	NS
Soil I	3.3	1.6	.6	.049	.0012	.072	.0018
Soil II	2.6	2.0	.6	.054	.0014	.071	.0018
Soil III	3.1	1.5	.5	.038	.0011	.058	.0016
LSD .05	.5	.5	NS	.010	.0003	.011	NS

order: L65-69 > L62-96 > CP52-68= L60-25, but in stubble cane was of the order: L65-69 = L62-96 > CP52-68 = L60-25.

Among fertilizer treatments and soil types, differences noted in Mn contents of plant parts did not appear important.

Zinc. — In plant cane (Table 33) the Zn content of millable cane in pounds per ton was statistically of the order: L65-69 = L62-96 = L60-25> CP52-68 and in stubble cane was of the order: L65-69> L62-96> CP52-68= L60-25. The Zn contents of above-ground parts in pounds per ton of millable cane did not differ significantly among varieties.

Zinc contents of plant and stubble cane generally were not related to fertilizer treatments or soil types.

Copper. — The Cu content of plant cane above-ground parts in pounds per ton of millable cane (Table 34) was of the order: L62-96 = CP52-68 = L65-69 > L60-25. A similar trend occurred in stubble cane.

Copper contents of plant and stubble cane were not related to fertilizer treatments.

Differences in Cu contents of plant and stubble cane related to soil types did not appear important.

Correlations Among Topsoil pH and Micronutrient Contents of Topsoil, Leaf Blades, and Above-Ground Parts

Correlation coefficients among topsoil pH and micronutrients in topsoil, leaf blades, and above-ground parts are contained in Table 35. Correlations among topsoil pH and micronutrients were discussed earlier from Table 5. With the exceptions of correlations discussed previously and those discussed below, the relationships appear to show no trends which may be of practical value when considering the micronutrition of sugarcane in Louisiana.

Topsoil pH. — Negative and highly significant correlations were found between topsoil pH and above-ground Zn and between topsoil pH and leaf-blade Zn of plant cane, but the relationships were not significant in stubble cane.

Iron, Manganese, Zinc, and Copper. — Extractable Fe was significantly correlated with above-ground Fe in plant cane (r=0.375), and highly significant negative correlations were noted between extractable Mn and above-ground Mn (r = -0.381) and between extractable Mn and leaf-blade Mn (r= -0.453). Leaf-blade Mn and above-ground Mn were highly correlated (r= 0.421).

In stubble cane the negative correlation between extractable Mn and above-ground Mn (r = -0.304) and positive correlation between leaf-blade Mn and above-ground Mn (r = 0.324) were significant.

No significant correlations were found among extractable Zn, above-ground Zn, and leaf-blade Zn, nor among extractable Cu, above-ground Cu, and leaf-blade Cu in plant or stubble cane.

Table 35. — Correlation coefficients (r)[1] among topsoil pH, micronutrients extractable from topsoil, and micronutrient contents of above-ground (AG) parts[2] and leaf blades (LB)

	Ext. Fe	AG Fe	LB Fe	Ext. Mn	AG Mn	LB Mn	Ext. Zn	AG Zn	LB Zn	Ext. Cu	AG Cu	LB Cu
						Plant Cane						
Topsoil pH	-.261	-.138	-.105	.457	.055	.034	.001	-.430	-.601	-.331	-.021	-.112
Ext. Fe		.375	.051	.038	-.358	-.203	.189	-.255	-.084	.291	-.066	.190
AG Fe			.083	-.057	-.107	-.005	-.021	.051	.024	.155	.090	.257
LB Fe				-.176	.033	.020	-.032	-.117	-.009	.057	-.084	.517
Ext. Mn					-.381	-.453	.151	-.429	-.360	.019	-.047	-.090
AG Mn						.421	.032	.339	-.064	.062	.363	.055
LB Mn							.135	.187	.133	.095	.256	.080
Ext. Zn								-.119	-.193	.840	-.018	-.134
AG Zn									.256	.103	.236	.088
LB Zn										.056	.221	.258
Ext. Cu											.124	.054
AG Cu												.273
						First Stubble Cane						
Topsoil pH	-.261	.312	.470	.457	.231	-.248	.001	-.080	.190	-.331	-.079	-.051
Ext. Fe		-.176	-.209	.038	-.183	.304	.189	-.336	-.204	.291	-.076	-.020
AG Fe			.101	.308	.414	-.041	.045	.190	-.044	-.015	.358	.163
LB Fe				.002	.309	.016	.081	-.034	.587	-.152	-.340	.004
Ext. Mn					-.304	-.104	.151	-.172	.092	.019	.034	.109
AG Mn						.324	.031	.462	.052	-.033	.203	.245
LB Mn							.104	.184	.257	.218	.327	.219
Ext. Zn								.053	-.085	.840	.090	-.016
AG Zn									.009	.117	.347	.151
LB Zn										-.127	-.091	.268
Ext. Cu											.245	.059
AG Cu												.069

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[1] Least significant r at 1% level = .369. Least significant r at 5% level = .285.

[2] Above-ground parts in fractional part of a pound per ton of millable cane.

Summary and Conclusions

Field, laboratory, and statistical data were obtained in an investigation of the effect of N and K fertilizers and soil types on yield, yield components, and nutrient uptake of four sugarcane varieties. The varieties were CP52-68, L60-25, L62-96, and L65-69. Fertilizer treatments in pounds per acre of N, P_2O_5, and K_2O applied to plant cane were 80-0-0, 80-0-80, 160-0-0, and 160-0-80. Fertilizers applied to first stubble cane were 120-0-0, 120-0-80, 240-0-0, and 240-0-80. Fertilizer P was not applied to the test site due to the residual effect of P from filter press mud which was applied to the area approximately 20 years before the investigation began. The study was conducted on soils which varied from Baldwin silt loam (Soil I) to Baldwin silt loam-Iberia clay (Soil II) to Iberia clay (Soil III).

Yield and yield component data were collected at three harvest periods from plant cane in 1973 and at three harvest periods from first stubble cane in 1974. The harvest periods were in early October (Harvest 1), early November (Harvest 2), and late November (Harvest 3). Topsoil and subsoil samples were taken in the spring prior to fertilization of plant cane and were analyzed for macronutrient and selected micronutrient contents. Leaf-blade samples were taken in early July, and samples of total above-ground parts or production were taken in early November of each crop year.

Tops and trash, bagasse, and juice from the above-ground samples were analyzed for macronutrient and micronutrient contents and were reported separately and in combination. Nutrient contents of bagasse and juice were added and reported as elemental contents of millable cane in pounds per acre and pounds per ton, and nutrient contents of tops and trash, bagasse, and juice were added and reported as elemental contents of above-ground parts in pounds per acre and pounds per ton of millable cane.

In the summary and conclusions, comments concerning ''above-ground'' elements or elemental contents of ''above-ground parts'' refer to the total content expressed in pounds per ton of millable cane, and ''leaf'' generally equates to ''leaf blade.''

The small differences in mean nutrient contents of the plots on which varieties and fertilizer treatments were established apparently caused very little experimental bias.

As averages of variety and fertilizer treatments, macronutrient contents of soils were generally of the order: Soil III > Soil II > Soil I. Micronutrient contents of the three soils showed no consistent pattern.

From the plant cane crop, cane yield increases by each variety were approximately linear throughout the harvest periods. Sugar yield increases, however, were substantially larger from Harvest 1 to 2 than from Harvest 2 to 3. In stubble cane, yields of cane and sugar increased from Harvest 1 to 2, no increases occurred in cane yield from Harvest 2 to 3, and sugar yield increased from Harvest 2 to 3 only in CP52-68 and L62-96.

As averages of all controlled variables, sugar yields in plant cane from the varieties were of the statistical order: L65-69= L62-96> L60-25> CP52-68, whereas, the order in stubble cane was: L65-69 = L60-25 > L62-96> CP52-68.

In plant cane, yields of cane and sugar from the two levels of fertilizer N, as averages of all other variables, did not differ significantly, but application of fertilizer K resulted in highly significant increases in yields of cane, 1.39 tons per acre, and sugar, 382 pounds per acre. Sucrose content of normal juice from plant cane was not affected appreciably by the higher level of N, but with the addition of K was 0.28 percentage point higher in the early maturing varieties, L60-25, L62-96, and L65-69, and approached statistical significance.

As an average of the other variables, the higher level of N applied to stubble cane resulted in increases in cane and sugar yields from L65-69 and L62-96, but the increase in sugar yield from L62-96 only approached significance and was related to a significant variety x N interaction effect on sucrose. Sucrose content of normal juice from L62-96 was significantly lower (0.53 percentage point) due to higher N. Sucrose from CP52-68 was 0.39 percentage point lower, and from L65-69 was 0.28 percentage point higher due to the higher level of N, both of which approached significance. Cane and sugar yields and sucrose from L60-25 were not affected appreciably by higher levels of N, but in CP52-68 the higher level of N depressed the sugar yield significantly.

Application of fertilizer K to stubble cane was associated with highly significant increases in average yields of cane, 2.92 tons per acre, and sugar, 668 pounds per acre. The increase in yields of sugar, however, varied among varieties as was indicated by significant variety x K interaction effects on sugar yield and on sucrose content. Sugar yield increases due to K by L60-25 and L62-96 were highly significant, and the increase by L65-69 was significant, but the increase by CP52-68 was not significant. Sucrose from L62-96 increased significantly and from CP52-68 decreased significantly due to K. The average sucrose from the three harvests of the early maturing varieties increased 0.38 perrcentage point due to K, but the increases were of the order: Harvest 1> Harvest 2> Harvest 3. Additional work with early maturing varieties in eight tests during 1972-75 indicated corroborative results in that, in addition to net cane yield increases, sucrose increased substantially due to fertilizer K.

Cane yield averages from plant cane on Soils I and II were statistically equal but were higher than from Soil III. Sugar yield and sucrose averages from plant cane, however, were of the order: Soil III> Soil II> Soil I, but only the differences between Soils I and III were significant. Cane yield averages from stubble cane were statistically of the order: Soil I> Soil II= Soil III. Stubble cane sugar yield from Soil II was significantly higher than from Soil I and the yield from Soil III was intermediate. Sucrose contents from stubble cane were of the order: Soil III= Soil II> Soil I. Although sucrose from cane grown on Soil III was significantly higher than from Soil I in both plant and first stubble crops, results from sampling of second stubble on the test site in 1975 showed a significant reversal. These findings, coupled with mixed results in 1975 from work in two tests on soils near the Mississippi River, indicate a conclusion that no general trend appears to exist concerning sucrose content of cane grown on light- as opposed to heavy-textured soils in Louisiana.

Generally, mean stalk weights among varieties at all harvests of both plant and stubble cane were of the order: L62-96> L65-69 = CP52-68> L60-25, but they were not related to fertilizer treatments or soil types to an important degree.

In plant and stubble cane, stalk length among varieties at all harvests was of the order: L65-69 = CP52-68> L62-96> L60-25. There was a trend in plant cane for fertilizer K and stalk length to relate negatively, but the trend did not exist in stubble cane. There was also a trend in plant and stubble cane for stalk length to vary among soil types in the order: Soil I> Soil II> Soil III.

Stalk diameter was normally largest from L62-96 and smallest from CP52-68, but the differences were relatively small in stubble cane. Stalk diameter was not generally related to fertilizer treatments or soil types.

When considering all harvests, the number of millable stalks per acre was positively correlated with cane yield each crop year, but the correlation in stubble cane was higher. The number of millable stalks was negatively correlated with stalk weight in plant and stubble cane at all harvests.

Generally, plant cane yields from the three harvests were significantly correlated with corresponding stalk weights, lengths, and diameters. In stubble cane, six of the nine correlations were significant or highly significant.

In 11 of 12 determinations stalk weights from plant and stubble cane correlated to a significant or highly significant degree with corresponding stalk lengths and diameters.

From six measurements stalk length and diameter were negatively correlated at Harvest 2 of plant cane, and negative correlations between stalk length and diameter at Harvests 1 and 3 of stubble cane approached significance.

Juice extraction from plant and stubble cane was not significantly related to varieties, fertilizer treatments, or soil types.

Substantial lodging occurred in plant and stubble cane from all varieties except CP52-68, but degree of lodging was not significantly associated with fertilizer treatments or soil types.

Although N content of leaf blades from CP52-68 was lower in plant and stubble cane than from other varieties, the N content of above-ground parts did not vary significantly among varieties. The positive effect of higher rates of N applied to plant and stubble cane on leaf N contents was small but was consistent and substantially larger in above-ground parts. The tendency for total N content of topsoil to correlate negatively with leaf and above-ground N was attributed to the relatively poor aeration and the associated lower rate of organic matter oxidation and root activity in the heavier soils where total N content of soils was highest. The association between leaf N and above-ground N was positive in plant (r = 0.217) and stubble cane (r = 0.333) but was significant only in stubble cane.

Leaf and above-ground S contents did not differ appreciably among varieties and fertilizer treatments. Leaf S in plant and stubble cane and above-ground S in plant cane were statistically of the order: Soil I > Soil II=Soil III, whereas, ''Soil'' and extractable S in topsoil were of the order: Soil I < Soil II = Soil III. Correlations between leaf S and above-ground S in plant (r = 0.676) and stubble cane (r= 0.482) were highly significant. Plant parts in stubble cane generally were substantially lower in S content than plant parts in plant cane, which indicated some depletion of ''Soil'' and/or extractable (available) S due to removal of S by the plant cane crop.

The P contents of leaf blades and above-ground parts from L65-69 were substantially higher than from other varieties but did not differ appreciably among fertilizer treatments or soil types. Extractable soil P and leaf P were not correlated significantly in plant or stubble cane. Correlation between extractable P and above-ground P was significant only in plant cane (r = 0.311). Correlations between leaf P and above-ground P were highly significant in plant and stubble cane (r = 0.613 and r = 0.446, respectively). It was concluded that the high amount of P in juice from L65-69 may contribute to better juice clarification in milling operations. Due to a relatively high amount of P removed in millable cane and trash from L65-69, it was also concluded that application of fertilizer P may be required when the variety is grown on soils normally considered adequate in P status or application of a higher rate than normal on soils considered to require fertilizer P.

Although the K content of leaf blades from CP52-68 was relatively low in plant and stubble cane, K contents of above-ground parts showed no consistent trend among varieties. Fertilizer K had a positive and generally significant effect, and fertilizer N had no significant effect on K contents of leaf blades and above-ground parts from plant and stubble cane. Among soils the K content of above-ground parts was of the order: Soil III> Soil II> Soil I. Correlations among extractable soil K, leaf blade K, and above-ground K was positive and generally significant or highly significant.

Differences among varieties and fertilizer treatments in Ca and Mg contents of leaf blades and above-ground parts from plant and stubble cane apparently were not important since all of the contents were considered high when compared to critical levels. The Ca and Mg contents of soils generally were of the order: Soil III> Soil II> Soil I, whereas Ca and Mg contents of leaf blades and above-ground parts from plant and stubble cane were generally in the reverse order. Correlations between extractable soil Ca and leaf and above-ground Ca were negative but were not supported statistically as strongly as negative correlations between extractable soil Mg and leaf and above-ground Mg. Correlations between leaf Ca and above-ground Ca were highly significant in plant and stubble cane ($r = 0.621$ and $r = 0.548$, respectively). Correlation between leaf Mg and above-ground Mg was significant only in plant cane ($r = 0.366$).

No important relationships were noted among varieties, fertilizer treatments, and soil types, and the Fe, Mn, Zn, and Cu contents of leaf blades from plant and stubble cane. Generally, the Fe and Mn contents of leaf blades were substantially higher, and Zn and Cu contents were equal to or higher, than critically low levels reported by other workers.

Although some differences were found in above-ground micronutrient contents among varieties, fertilizer treatments, and soil types, the differences were not considered important since no yield responses to micronutrients have been observed in Louisiana (*8*, *9*, *13*, *32*).

As an average of all controlled variables in the experiments, the Fe, Mn, Zn, and Cu contents of millable cane in pounds per ton were 0.036, 0.0055, 0.0069, and 0.0012, respectively. In Florida (*1*), the Fe, Mn, Zn, and Cu contents of millable cane and trash, which varied from about 3 to 18 percent, were 0.021, 0.0050, 0.0051, and 0.0016 pounds per ton, respectively. The Florida micronutrient data were obtained only from the last of 11 crops of cane on the same experimental site. Yield data were obtained from all of the 11 crops, each of which had received treatments with Fe, Mn, Zn, and Cu in various combinations, but there were no significant differences in tons of cane or sugar per acre due to treatments nor were deficiency symptoms observed.

Literature Cited

1. Andreis, H. J. 1975. Macro and micro nutrient content of millable Florida sugarcane. The Sugar Journal 1:10-12.
2. Association of Official Agricultural Chemists. 1960. Official Methods of Analysis. Washington, D. C. Ed. 9.
3. Bardsley, C. E., and J. D. Lancaster. 1960. Determination of reserve sulfur and soluble sulfate in soils. Soil Sci. Soc. Am. Proc. 24:265-268.
4. Baver, L. D. 1960. Plant and soil composition relationships as applied to cane fertilization. Hawaiian Planters' Record, 56:43.
5. Borden, R. J. 1946. The influence of certain mineral substances on the quality of sugarcane. Hawaiian Planters' Record, 50:59-64.
6. Bowen, J. E. 1975. Recognizing and satisfying the micronutrient requirements of sugarcane. Sugar y Azucar. Nov: 15-18.
7. Brupbacher, R. H., W. P. Bonner and J. E. Sedberry. 1968. Analytical methods and procedures used in the Soil Testing Laboratory. La. Agr. Exp. Sta. Bull. 632.
8. Davidson, L. G. 1954-61. Fertilizer investigations on sugarcane. Unpublished data, ARS, USDA, Houma, La.
9. De Ment, J. D., and M. B. Sturgis. 1949. Complete fertilizers for sugarcane. Report of Projects, Dept. of Agronomy, La. Agr. Exp. Sta.
10. Du Toit, J. L. 1959. Recent advances in nutrition of sugarcane in South Africa. Proc. ISSCT 10:432-441.
11. Evans, H. 1965. Tissue diagnostic analyses and their interpretation in sugarcane. Proc. ISSCT 12:156-180.
12. Golden, L. E. 1964-75. Fertilizer and soil fertility studies with sugarcane. Report of Projects, Dept. of Agronomy, La. Agr. Exp. Sta.
13. ————————. 1976. Micronutrient studies with sugarcane in Louisiana. Proc. ASSCT Vol. 6 (in press).
14. ————————. 1974. Nutrient availability and uptake by sugarcane. Report of Projects, Dept. of Agronomy, La. Agr. Exp. Sta.
15. ————————. 1971. Relationship between fertilizer and leaf blade P and S and sugarcane yield in Louisiana. Proc. ISSCT 14:695-701.
16. ————————. 1975. The effect of sugarcane production on nutrient contents of Mhoon and Jeanerette silt loams. La. Agr. Exp. Sta. Bull. 685.
17. ————————. 1971. The relationship of P, K, Ca and Mg extractable from soils to P, K, Ca and Mg contents of sugarcane leaf blades. Proc. ASSCT Vol. 1.
18. ————————. 1973. Yield and nutrient element content of roots and below-ground stubble as related to fertilization of sugarcane and soil variation. Proc. ASSCT Vol. 3.
19. ————————, and R. Ricaud. 1965. Foliar analysis of sugarcane in Louisiana. La. Agr. Exp. Sta. Bull. 588.
20. ————————————————————. 1967. Sugarcane yield increases due to fertilizer in Louisiana. Sugar Bull. Vol. 45, No. 17.
21. ————————————————————. 1963. The nitrogen, phosphorus and potassium contents of sugarcane in Louisiana. La. Agr. Exp. Sta. Bull. 574.

22. ————————————————. 1964. Uptake of nitrogen, phosphorus, potassium, calcium, magnesium and sulfur by sugarcane in Louisiana. Sugar Bull. Vol. 42, No. 14.

23. Henderson, M. T., B. L. Legendre, and D. P. Viator. 1969. Investigations in 1969 on genetics of economic characters in sugarcane. Report of Projects. Dept. of Agronomy, La. Agr. Exp. Sta.

24. Humbert, R. P. 1953. Basic problems of sugarcane nutrition. II. Applying basic facts in sugarcane fertilization. Proc. ISSCT 8:71-79.

25. Juang, T. C. 1975. Trace element nutrition of sugarcane. Taiwan Food and Fert. Tech. Ctr. Ext. Bull. 54.

26. Karim, H. 1975. The distribution of the micronutrient cations in the genetic horizons of soils in Louisiana. Ph.D. Dissertation, Louisiana State University Library, Baton Rouge.

27. Lakshmikantham, M. 1974. Application of phosphate and potash and their effect on the juice quality of cane crops following heavy nitrogen fertilization. Proc. ISSCT 15:633-636.

28. Mariotti, J. A. 1971. Associations among yield and quality components in sugarcane hybrid progenies. Proc. ISSCT 14:297-302.

29. Parish, D. H. 1962. Fertilizers and the sugar industry of Mauritius. Proc. ISSCT 11:77-83.

30. Patrick, W. H., Jr., R. Wyatt, and R. H. Brupbacher. 1964. A study of chemical and physical properties of three alluvial soils in the sugarcane area of Louisiana. La. Agr. Exp. Sta. Bull. 580.

31. ————————, F. T. Turner, and R. D. Delaune. 1969. Soil oxygen content and root development of sugarcane. La. Agr. Exp. Sta. Bull. 641.

32. Ricaud, R. 1964-75. Effects of fertilizers on yield of sugarcane. Report of Projects, Dept. of Agronomy, La. Agr. Exp. Sta.

33. ——————. 1965. Soil potassium and response of sugarcane to fertilizer potassium in Louisiana. La. Agr. Exp. Sta. Bull. 594.

34. ——————, and L. E. Golden. 1964. Calcium and magnesium uptake by sugarcane in Louisiana. Sugar Bull. Vol. 43, No. 6.

35. Samuels, G., and P. Landrau, Jr. 1956. The sucrose content of sugarcane as influenced by fertilizers. Proc. ISSCT 9:365-374.

36. Sedberry, J. E., Jr., F. J. Peterson, E. Wilson, A. L. Nugent, R. M. Engler, and R. H. Brupbacher. 1971. Effects of zinc and other elements on the yield of rice and nutrient content of rice plants. La. Agr. Exp. Sta. Bull. 653.

37. Sornay, A. D., and O. Davidson. 1959. Relationship between growth of cane and yield of cane at harvest. Proc. ISSCT 10:390-398.

38. Tabayoyong, F. T. 1959. The effects of soil type and fertilization on the yield of cane in the Philippines. Proc. ISSCT 10:398-407.

39. Tonimoto, T. and G. Burr. 1959. The growth of sugarcane as influenced by nitrogen fertilization. Proc. ISSCT 10:450-461.

40. Walkley, A., and I. A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chronic acid titration method. Soil Sci. 37:29-38.

41. Wang, S. C. 1954. Taiwan sugarcane soils and fertilizers. Proc. ISSCT 8:117.

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Responses of Bahiagrass to Applied Nitrogen Phosphorus and Potassium

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lletin No. 701 **June 1977**

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Responses of Bahiagrass to Applied Nitrogen, Phosphorus, and Potassium

Marvin Allen[1], P. E. Schilling[2], E. A. Epps[3],
C. R. Montgomery[4], B. D. Nelson[5], and R. H. Brupbacher[6]

INTRODUCTION AND OBJECTIVES

More acreage in the southeastern United States is better adapted for grassland farming than for row cropping. Competition between man and animals for protein and energy could be lessened by increased production and utilization of forage by ruminants. Ruminants have the unique ability to obtain a major portion of their nutritional needs from forages, converting them into high quality nutrients for human consumption.

It has been demonstrated that meat-type ruminants perform satisfactorily on a forage diet supplemented only with minerals. Ruminants used for milk production can utilize forages to obtain one-half or more of their total nutritional needs.

Bahiagrass, *Paspalum notatum* Flugge, a warm-season perennial grass, is utilized extensively in the southeastern United States for beef and milk production. This grass, when properly fertilized and managed, provides up to 6 months of grazing and is one of the main sources for hay.

An experiment was conducted with various levels and ratios of nitrogen, phosphorus, and potassium applied to 'Pensacola' bahiagrass. The objectives of this study were:

(1) To characterize forage yield and nutrient content throughout the growing season.
(2) To characterize relative forage quality throughout the growing season.
(3) To evaluate changes in soil analysis values in response to treatments.

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REVIEW OF LITERATURE

Allen, *et al.* *(1)*[7] reported that in 1970 forages comprised 54 percent of the energy consumed by all farm livestock in the United States. Of the total energy ingested, hay provided 12 percent, other harvested forage 6 percent, and pasture 36 percent. Each forage-consuming animal unit required 1.2 tons per year hay equivalent. Pasture supplied a greater proportion of the dietary energy than any other feed for non-milking dairy cattle (46 percent) and non-fattening beef cattle (72 percent). Forage of all sources supplied 62 percent of the dietary energy to lactating cows, 81 percent to other dairy cattle, and 91 percent to all beef cattle not on fattening rations.

Bahiagrass, native to South America, was first introduced into the United States in 1913 by the Florida Agricultural Experiment Station (*10*).

Ward and Watson (*13*) summarized some of the more important aspects and related research findings of bahiagrass as a forage crop. It is a deep rooted warm-season perennial with exposed rhizomes that forms a dense sod. Bahiagrass is a popular pasture grass in the South because: (a) it tolerates a wider range of soil conditions than does bermudagrass, *Cynodon dactylon* (L.) Pers., or dallisgrass, *Paspalum dilatatum* Poir.; (b) it is resistant to encroachment of weeds; (c) it is established by seed; (d) it is relatively free from damaging insects and diseases; (e) it produces moderate yields on soils of low fertility; and (f) it withstands close grazing. They also stated that beef gains on bahiagrass were intermediate to gains on common and 'Coastal' bermudagrass. Bahiagrass pasture or hay is not satisfactory as the sole source of feed for high-producing dairy cows. Forage quality is highest in early spring, but by mid-summer the percentage of cell wall constituents (CWC) is sufficiently high to suggest that animal intake would be limited.

Allen *(2)* reported that yields of 'Pensacola' bahiagrass and common bermudagrass were similar, but both were lower than that of three hybrid bermudagrasses, when all were managed similarly. Leaf content of the forage was higher in 'Pensacola' than in the bermudagrasses. 'Pensacola' bahiagrass and 'Coastcross 1' bermudagrass were higher in digestibility than were the other grasses as measured by in vitro (*12*), nylon bag in vivo *(8)*, and animal feeding trials.

Brouwer (*5*) stated that the Ca: P ratio is of considerable importance in the diet of ruminants and that a disease resembling rickets develops if this ratio is too high or too low. Ratios of K:Na, K:Ca, Na:Ca, Mg:P, Ca:Mg, and probably others are important in animal nutrition and health. An important point of consideration is that a change in the ratio of any two elements cannot occur alone without affecting other ratios.

National Research Council (*9*) data indicate that the following ranges in mineral content (on a dry matter basis) are considered adequate in a forage diet for a beef cow with a calf at her side: 2.5 to 3.0 percent nitrogen, 0.26 to 0.32 percent phosphorus, 1.8 to 2.1 percent potassium, 0.22 to 0.25 percent calcium, and 0.16 to 0.20 percent magnesium.

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[7] Italic numbers in parentheses refer to Literature Cited, page 31.

Garmans *et al.* (*7*) summarized from available data the approximate pounds per acre of nutrients contained in some forage crops. For example, 'Coastal' bermudagrass, with a yield of eight tons per acre, removed the following amounts of nutrients: 300 pounds of nitrogen, 70 pounds of phosphorus (P_2O_5), 270 pounds of potassium (K_2O), 59 pounds of calcium, 24 pounds of magnesium, and 35 pounds of sulfur.

Allen *et al.* (*3*) reported an approximate 1.5 percentage unit increase in the crude protein content of an oat-ryegrass mixture with each 100-pound increase of applied nitrogen. The potassium concentration was higher in the unfertilized forage than in forage that received 100 pounds of K_2O per acre. Applications of K_2O suppressed the calcium and magnesium concentrations in the forage. Applications of fertilizer did not appreciably affect the in vitro dry matter digestibility of the forage.

EXPERIMENTAL PROCEDURE

The experiment was conducted on a Lexington silt loam soil at the Southeast Louisiana Dairy and Pasture Experiment Station, Franklinton. 'Pensacola' bahiagrass was established in 1966. Three tons of dolomitic limestone per acre were incorporated into the soil prior to seeding of the experimental area. Chemical analysis values of soil samples taken to a 6-inch depth prior to sod establishment were as follows, in extractable parts per million: phosphorus—34, potassium—100, calcium—227, magnesium—145, and the soil reaction was pH 5.6.

The experimental design was a randomized complete block with four replications. Three levels of nitrogen (200, 300, and 400 pounds per acre), phosphorus (100, 200, and 300 pounds per acre expressed as P_2O_5), and potassium (100, 200, and 300 pounds per acre expressed as K_2O) were applied annually in a factorial arrangement of treatments. For base line information, nine additional treatments were included in which one or more of the plant nutrients was not applied. Treatments were imposed and data were collected from 1967 through 1971. The 36 treatments are summarized as follows:

		Pounds plant nutrients per acre applied annually		
N		P_2O_5		K_2O
200		100		100
300	X	200	X	200
400		300		300
0		0		0
200		0		0
0		200		0
0		0		200
200		200		0
200		0		200
0		200		200
300		0		0
400		0		0

The sources of fertilizer material used were ammonium nitrate (33.5 percent N), triple superphosphate (46 percent P_2O_5), and muriate of potash (62 percent K_2O). All of the P_2O_5 and K_2O and one-half of the N of the respective treatments were applied broadcast in late March each year. Of the remaining N, one-half was applied in mid-June and one-half in mid-August.

The overall plot size was 10′ x 21′, the fertilized area was 8′ x 20′, and the harvested area was 4′ x 16′.

A 5-week harvest interval was used the first season, and a 3-week harvest interval was used for the remaining four seasons. Forage was clipped to a 3-inch stubble height at each harvest with a sickle-bar mower. Green weights were recorded, and samples of the forage were dried in a forced-air, thermostatically controlled dryer. Drying temperature did not exceed 135° F. Dried forage samples were ground in a Wiley mill with a 1-mm screen for laboratory determinations.

Determinations of crude protein, P, K, Ca, and Mg of the forage were made according to A.O.A.C. procedures (*4*). Cell wall constituents, acid detergent fiber, and in vitro digestible dry matter were determined by the Van Soest procedure (*12*). The in vitro digestible dry matter procedure was modified by adding glucose and urea to the buffer solution. All data relative to the forage are reported on a dry matter basis.

Soil samples were taken from all plots annually in early March. Sampling depth was 6 inches. The analytical methods and procedures used to determine extractable elements and soil reaction are described in Louisiana Agricultural Experiment Station Bulletin No. 632 (*6*).

Statistical analyses of the data were conducted according to Snedecor and Cochran (*11*). The yield data from all years were pooled over replications, and an analysis of variance was conducted for each variable, using years as replications. An analysis of variance was conducted for the 3 x 3 x 3 factorial arrangement of treatments and for all 36 treatments. All data were recorded by clipping date. A stepwise regression analysis of each variable on clipping date, recorded as number of days from the base date of April 1, was conducted where the linear, quadratic, cubic, and quartic terms for clipping date were evaluated. Regression analyses were conducted for each level of N, P, and K in the factorial arrangement, for specific combinations of N, P, and K, and for the control treatment (no fertilizer applied).

RESULTS AND DISCUSSION

Forage Yield

Average total yield of dry forage in response to combinations of applied nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) are reported in Table 1.

An increase of applied N from 200 to 300 pounds per acre increased the average yield of forage by 2,106 pounds. The yield increase was 1,173 pounds as N was increased from 300 to 400 pounds per acre. As N rates were increased from 200 to 400 pounds, pounds of forage yield per pound of added N declined from 21 to 11.7.

Table 1.—Mean effects of applied N, P_2O_5, and K_2O on the dry forage yield of Pensacola bahiagrass, 5-year average

N lbs/a	P_2O_5, lbs/a 100	200	300	Avg.
	Forage, lbs/a			
200	10,590 a1	10,664 a2	10,820 a3	10,691 a
300	12,736 b1	12,722 b2	12,932 b3	12,797 b
400	13,692 c1	14,081 c2	14,138 c2	13,970 c
P_2O_5 lbs/a	K_2O, lbs/a 100	200	300	Avg.
	Forage, lbs/a			
100	11,916 a1	12,327 a2	12,775 a3	12,339 a
200	12,066 b1	12,524 b2	12,877 b3	12,489 b
300	12,019 b1	12,814 c2	13,057 c3	12,630 c
K_2O lbs/a	N, lbs/a 200	300	400	Avg.
	Forage, lbs/a			
100	10,381 a1	12,539 a2	13,181 a3	12,001 a
200	10,819 b1	12,775 b2	14,071 b3	12,555 b
300	10,873 b1	13,176 c2	14,660 c3	12,903 c

Means with same letter within columns or same number within rows do not differ significantly at $P < .05$.

Within levels of applied P_2O_5 and K_2O, forage yield increased significantly with increased levels of N.

Increases in forage yield from increased levels of P_2O_5 were numerically small but statistically significant. Additional P_2O_5 above 100 pounds per acre accounted for increases of only 150 and 291 pounds of forage per acre.

There was a linear yield increase of approximately 500 pounds of forage with each increase in applied K_2O above the 100-pound rate.

From a forage yield standpoint, within 200- and 300-pound N rates, yield response to more than 100 pounds per acre each of applied P_2O_5 and K_2O would not be justified economically. With 400 pounds of applied N, 100 pounds of P_2O_5 and 200 pounds of K_2O were more practical than were the higher rates.

Forage yields from treatments that had one or more of the major plant nutrients omitted are shown in Table 2. The absence of applied N had the most profound effect of any one of the three nutrients on lowering yield. Comparison of yield values in Tables 1 and 2 indicates the need for application of a complete fertilizer for improved forage production. Application of 200 pounds of N alone resulted in about 2,000 pounds less forage than when 200 pounds of N with P_2O_5 and K_2O were applied.

Differences in average yield of all treatments among years were due mainly to amount and distribution of rainfall within the respective seasons. For example, in spite of adequate fertilizer and good management, the lack of moisture in 1968 limited expression of the better treatments.

Table 2.—Forage yield of Pensacola bahiagrass in response to selected fertilizer applications and yearly average

Applied, lbs/a			
N	P_2O_5	K_2O	Forage lbs/a
0	0	0	3,424 a
200	0	0	8,662 c
200	200	0	9,179 d
200	0	200	9,732 e
0	200	0	3,461 ab
0	0	200	3,670 b
0	200	200	3,384 a
300	0	0	9,034 d
400	0	0	9,614 e
Year effects, average of all treatments			
1967			12,609 d
1968			8,327 a
1969			9,441 b
1970			13,649 e
1971			11,151 c

Means with same letter in columns within groups significantly different at $P < .05$.

In grassland farming, seasonal distribution of forage produced may be as important as the total amount of forage produced. The distribution of bahiagrass produced through the season in response to applied N levels is shown in Figure 1.

Distribution of bahiagrass yield, with or without applied fertilizer, was generally curvilinear. Yield peaked in July for the 200-pound N rate, and in August for the 300- and 400-pound rates. The higher N rates delayed seedhead production of the bahiagrass, a period when dry matter accumulation is generally highest. Yields were lower at the end of the season than at the beginning of the season for all N levels. Smaller differences were noted throughout the season between the 300- and 400-pound N rates than between the 200- and 300-pound rates.

The distribution in yield of the non-fertilized forage varied less throughout the season than did that of the fertilized forage. These data indicate that change in stocking rate over the season would be necessary to efficiently utilize this grass as a grazing crop. An alternative would be to harvest excess forage as hay.

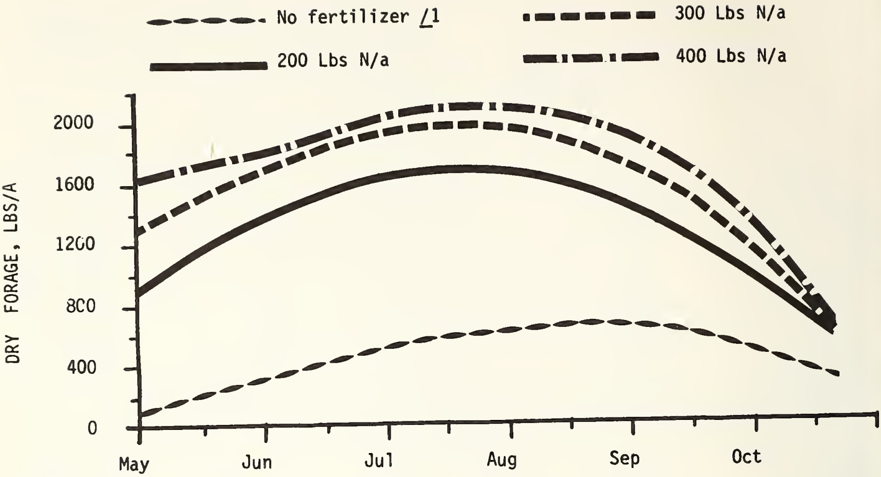

Figure 1.—Seasonal and mean effects of applied N on forage yield of bahiagrass. Average of eight clippings per year over 5 years.
[1]**Base line information only.**

Nutrient Content

Crude Protein

Crude protein content in the bahiagrass responded consistently to level of applied N throughout the season (Figure 2). There was a significant increase in protein with increased levels of applied N. A sharp decrease in protein occurred in May and June, with a gradual increase beginning in early August. The slight but continuous increase in protein in the latter part of the season was due in part to the fact that bahiagrass produces seedheads most profusely in mid-summer and then becomes more vegetative as the season progresses. There was about a 1 percentage unit increase in protein over the season for each 100-pound increase in applied N above the 200-pound rate.

Protein content of the non-fertilized forage was consistently lower than that of the fertilized forage, but the seasonal trends were similar. The protein in the fertilized forage was generally not high enough to meet the protein requirements of a beef cow with a calf at her side except in early May.

Phosphorus

Phosphorus content in the forage was altered significantly by level of applied P_2O_5 and by time within the season (Figure 3). The magnitude of increases in phosphorus content were rather consistent among rates of applied P_2O_5 throughout the season. A sharp decline in phosphorus content

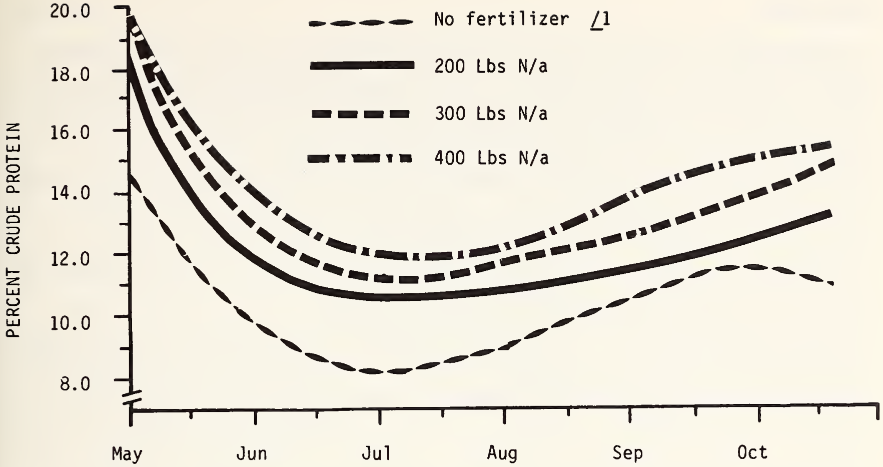

Figure 2.—Seasonal and mean effects of applied N on protein content in bahiagrass. Average of eight clippings per year over 5 years.

[1]**Base line information only.**

occurred in May followed by a gradual increase from mid-July to early October. In mid-June only the non-fertilized forage had a phosphorus content below that considered adequate to meet the needs of a beef cow and calf. Annual applications of 100 pounds of P_2O_5 per acre meet phosphorus requirements for forage production and ruminant nutrition.

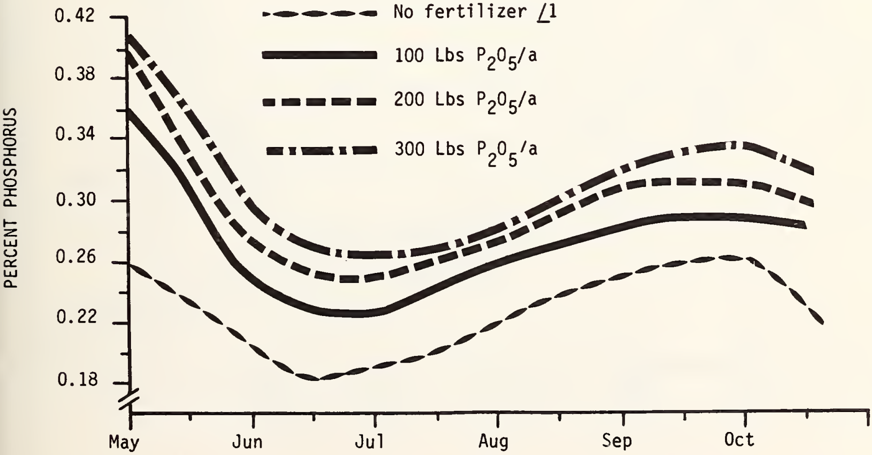

Figure 3.—Seasonal and mean effects of applied P_2O_5 on phosphorus content in bahiagrass. Average of eight clippings per year over 5 years.

[1]**Base line information only.**

Potassium

Potassium content in the bahiagrass forage throughout the season is shown in Figure 4. Potassium content was consistently higher throughout the season in response to higher rates of applied K_2O; however, there was a greater increase in potassium content when the applied K_2O went from 100 to 200 pounds than when the rate went from 200 to 300 pounds per acre. Following a sharp decline in May, there was a rather gradual decrease in potassium content of the forage for the remainder of the season.

Potassium content of the non-fertilized forage was lower than that of the fertilized forage throughout the entire season.

Little is known about the minimum requirement of potassium in forage for ruminants. It has been suggested by the National Research Council that a forage potassium level of 1.2 percent be considered minimal. Forage that received 100 pounds of K_2O per acre was at or above the proposed minimum until about mid-August. Potassium in the non-fertilized forage was below the minimum throughout the season except in early May.

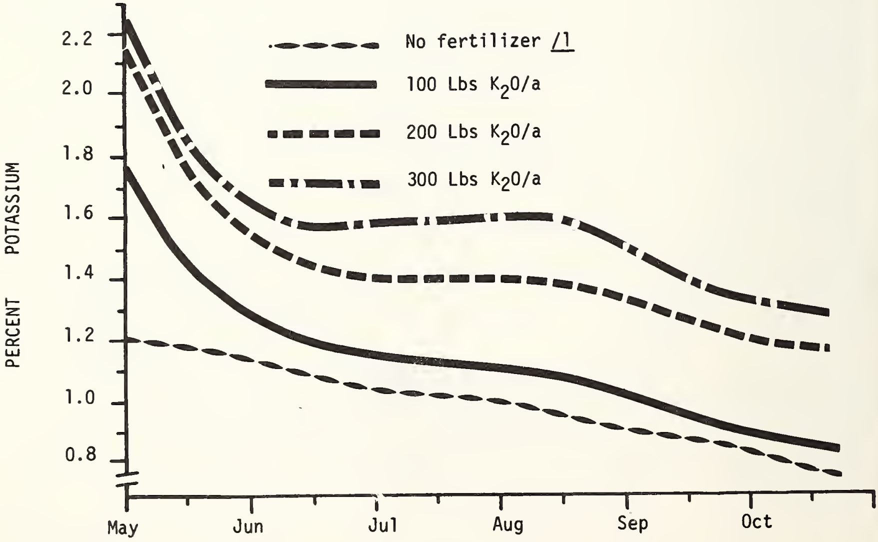

Figure 4.—Seasonal and mean effects of applied K_2O on potassium content in bahiagrass. Average of eight clippings per year over 5 years.

[1]Base line information only.

Calcium

Increased rates of applied K_2O had a significant effect on decreasing the calcium content in bahiagrass (Figure 5). Seasonal effect was greater than was the effect of K_2O on the calcium content of the forage. The seasonal distribution of calcium was curvilinear. Decline of calcium in the forage during May was more rapid than was the increase over the remainder of the season. Calcium content for the respective treatments was nearly as high at the end of the season as at the beginning of the season. From mid-May to mid-July the calcium content in the non-fertilized forage was essentially the same as that in the forage that received 100 pounds of K_2O.

Although not illustrated in a graph, applied N increased the calcium content in the forage. The increase in calcium content with increased N was approximately half the magnitude of the effect that applied K_2O had on decreasing calcium content.

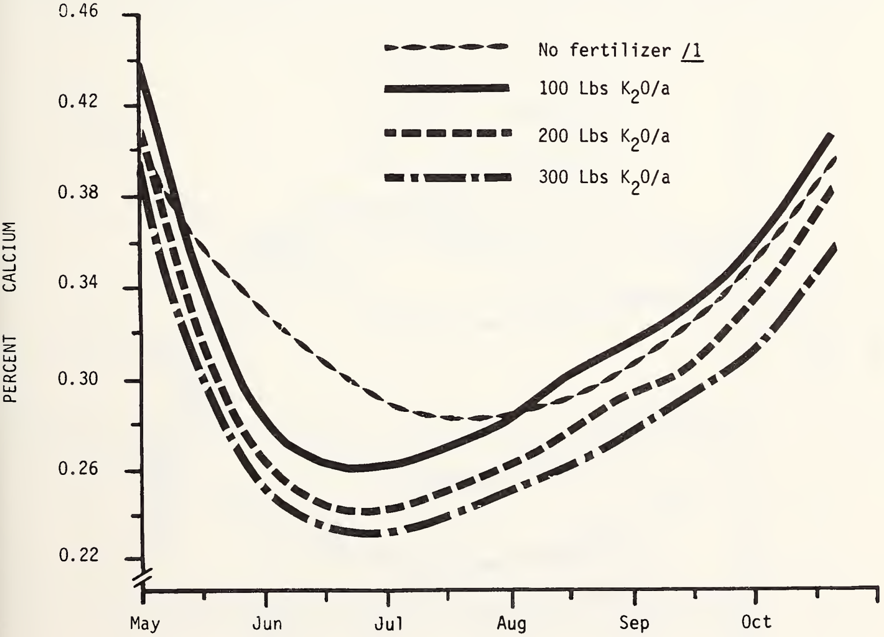

Figure 5. — Seasonal and mean effects of applied K_2O on calcium content in bahiagrass. Average of eight clippings per year over 5 years.

[1] Base line information only.

Magnesium

Magnesium content in the forage decreased significantly as K_2O rates were increased from 100 to 300 pounds per acre (Figure 6). Seasonal effect on magnesium content with respect to applied K_2O throughout the growing period was generally similar. There was a general trend for the magnesium content to decrease during the first half of the season, and then to increase during the latter half of the season. Magnesium was higher in the fertilized forage at the end of the season than at the beginning of the season.

There was no seasonal effect on magnesium content in the non-fertilized forage.

Increased N rates elevated magnesium content, but to a lesser extent than applied K_2O lowered it.

Forage Quality

One of the more recent methods of estimating forage quality is a measure of cell wall constituents (CWC). It represents the fibrous portion of plants

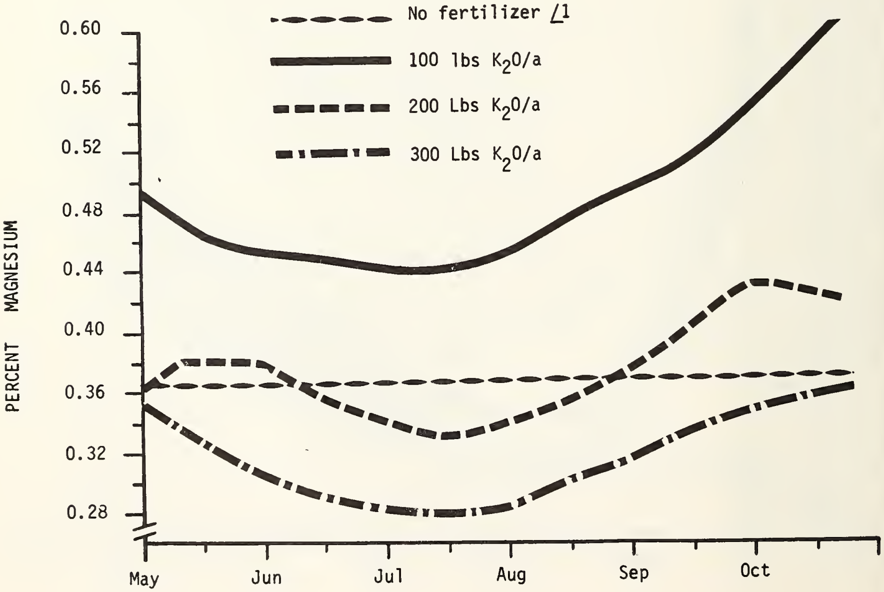

Figure 6.—Seasonal and mean effects of applied K_2O on magnesium content in bahiagrass. Average of eight clippings per year over 5 years.

[1]Base line information only.

that is acted on by microflora in the rumen. It makes up the major portion of plants, and generally, the higher the CWC in a forage the lower the quality of that forage.

Effects of applied N on CWC of bahiagrass are shown in Figure 7. Application of 400 pounds of N per acre resulted in a consistently lower CWC than did either the 200- or 300-pound rates. The response of CWC to the two lower N rates was inconsistent over the season. The non-fertilized forage was generally higher in CWC than were the fertilized forages. These CWC values represent differences too small to be detected with animals.

CWC of the fertilized forage increased approximately 10 percentage units from early May to late June. Thereafter, CWC declined gradually to the end of the season. It is apparent from these data that the relative quality of bahiagrass is highest in early spring. Excess forage produced in May should be harvested as high quality hay. It appears that little can be done through the use of fertilizer to alter the seasonal effect on CWC.

Acid Detergent Fiber

Acid detergent fiber (ADF) may represent a more realistic estimate of forage fiber than crude fiber because lignin is included in ADF. Small but significant differences in ADF among N levels were detected (Figure 8).

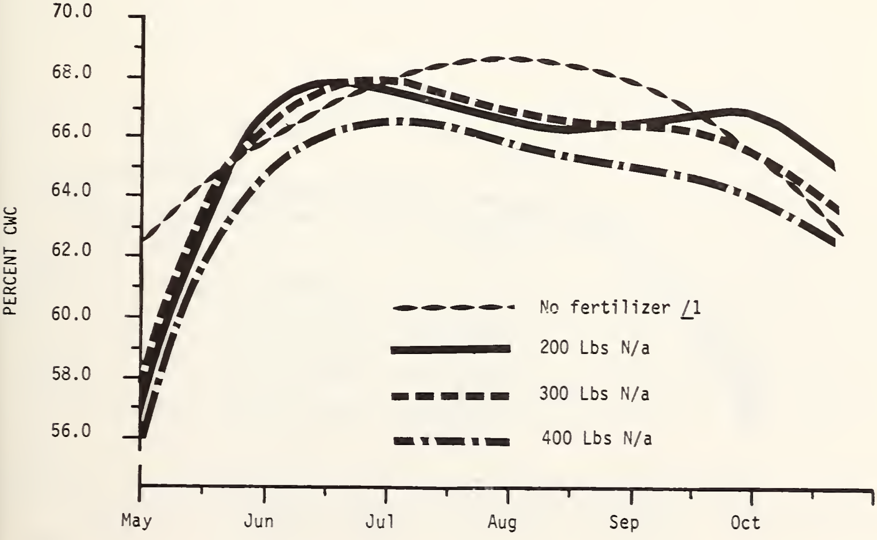

Figure 7.—Seasonal and mean effects of applied N on cell wall constituents (CWC) content in bahiagrass. Average of eight clippings per year over 5 years.

[1] **Base line information only.**

ADF values were consistently lowest at the 400-pound N rate throughout the season.

Non-fertilized forage was higher in ADF than were the fertilized forages. The major increase of ADF in the fertilized forages—above 5 percentage units—occurred in May and early June. There was an increase of ADF in the non-fertilized forage from May to August. The trends for CWC and ADF (Figures 7 and 8) were quite similar throughout the season. On the average, over the season, ADF accounted for slightly more than half of the CWC, with the difference being made up mainly by hemicellulose.

In Vitro Digestible Dry Matter

In vitro digestible dry matter (DDM) is generally regarded as a relative measure of the nutritional value of a forage. DDM values, as affected by N applications, are shown in Figure 9. Less than 1 percentage unit difference was detected in DDM among N rates throughout most of the season. All the fertilized forages decreased in DDM by about 12 percentage units from May to July.

There was no apparent effect of time on DDM in the non-fertilized forage. The DDM of the fertilized forages approximated that of the non-fertilized forage from about mid-June to mid-August.

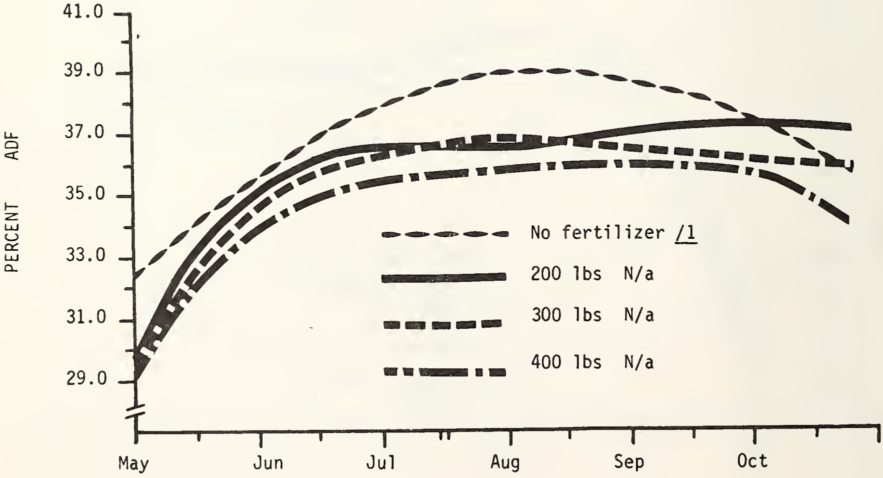

Figure 8.—Seasonal and mean effects of applied N on acid detergent fiber (ADF) content in bahiagrass. Average of eight clippings per year over 5 years.

[1]Base line information only.

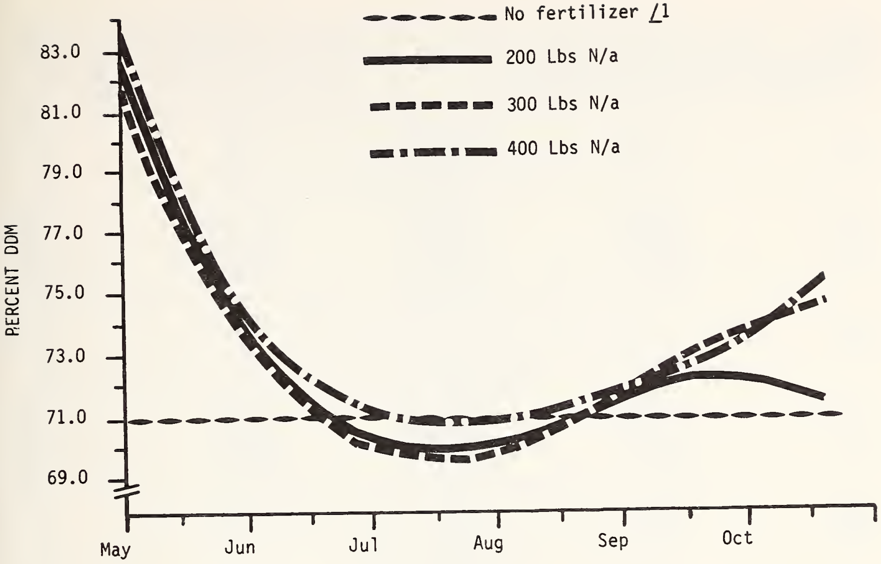

Figure 9.—Seasonal and mean effects of applied N on in vitro digestible dry matter (DDM) content in bahiagrass. Average of eight clippings per year over 5 years.
[1]Base line information only.

Plant Nutrient Removal

Nitrogen

A measure of nutrient removal by harvested forage aids in evaluating treatment effects in a forage crop experiment. The nutrients reported are expressed as pounds per acre in their respective elemental or oxide forms.

Nitrogen removal in the harvested forage of bahiagrass, as affected by applications of N, P_2O_5, and K_2O, is reported in Table 3. Nitrogen removal was increased by approximately 50 pounds per acre with each additional 100 pounds increase in applied N above the 200-pound rate. This trend was fairly consistent for the N rates among the P_2O_5 rates but not among K_2O rates.

There was a significant increase in N removal of an average of only 5 pounds per acre as applied P_2O_5 was increased from 100 to 300 pounds per acre.

Increasing the applied K_2O from 100 to 200 and from 200 to 300 pounds per acre increased average N removal by 10 and 6 pounds, respectively. Nitrogen removal was increased with increased N and K_2O rates applied.

Table 3.—Mean effects of applied N, P_2O_5, and K_2O on N removal in Pensacola bahiagrass forage, 5-year average

N lbs/a	P_2O_5, lbs/a 100	200	300	Avg.
	N removal, lbs/a			
200	200 a1	205 a1	206 a1	204 a
300	256 b1	255 b1	262 b2	258 b
400	296 c1	303 c2	302 c2	300 c

P_2O_5 lbs/a	K_2O, lbs/a 100	200	300	Avg.
	N removal, lbs/a			
100	243 a1	251 a2	258 a3	251 a
200	247 a1	256 ab2	260 a2	254 ab
300	247 a1	259 b2	263 a2	256 b

K_2O lbs/a	N, lbs/a 200	300	400	Avg.
	N removal, lbs/a			
100	199 a1	252 a2	285 a3	245 a
200	206 b1	257 a2	303 b3	255 b
300	206 b1	264 b2	312 c3	261 c

Means with same letter within columns or same number within rows do not differ significantly at $P < .05$.

Phosphorus

Applications of applied N significantly increased P_2O_5 removal by the forage (Table 4). There was a greater increase in P_2O_5 removal when applied N was increased from 200 to 300 pounds per acre than when it was increased from 300 to 400 pounds. More P_2O_5 was removed when 100 pounds of P_2O_5 was applied in combination with 400 pounds of N than when 300 pounds of P_2O_5 was applied with 200 pounds of N.

The average effects of applied P_2O_5 on P_2O_5 removal were essentially the same as that of applied N. This indicates that the applied N had as great an influence on P_2O_5 removal as did applied P_2O_5, within the rates tested.

Applied K_2O had little effect on P_2O_5 removal.

Potassium

Average K_2O removal increased 34 and 14 pounds per acre, respectively, as applied N increased from 200 to 300 and 400 pounds (Table 5).

The influence of applied P_2O_5 on K_2O removal was statistically significant but numerically small.

Table 4.—Mean effects of applied N, P_2O_5, and K_2O on P_2O_5 removal in Pensacola bahiagrass forage, 5-year average

N lbs/a	P_2O_5, lbs/a			Avg.
	100	200	300	
	- - - - - - - - - - P_2O_5 removal, lbs/a - - - - - - - - - -			
200	67 a1	73 a2	77 a3	72 a
300	78 b1	84 b2	90 b3	84 b
400	80 c1	88 c2	94 c3	87 c

P_2O_5 lbs/a	K_2O, lbs/a			Avg.
	100	200	300	
	- - - - - - - - - - P_2O_5 removal, lbs/a - - - - - - - - - -			
100	74 a1	75 a2	75 a2	75 a
200	80 b1	82 b2	82 b2	82 b
300	85 c1	88 c3	87 c2	87 c

K_2O lbs/a	N, lbs/a			Avg.
	200	300	400	
	- - - - - - - - - - P_2O_5 removal, lbs/a - - - - - - - - - -			
100	72 b1	84 a2	84 a2	80 a
200	74 c1	85 b2	87 b3	82 b
300	71 a1	84 a2	90 c3	82 b

Means with same letter within columns or same number within rows do not differ significantly at $P < .05$.

Table 5. — Mean effects of applied N, P_2O_5, and K_2O on K_2O removal in Pensacola bahiagrass forage, 5-year average

N lbs/a	P_2O_5, lbs/a			Avg.
	100	200	300	
	- - - - - - - - - - K_2O removal, lbs/a - - - - - - - - - -			
200	186 a1	189 a2	192 a3	189 a
300	220 b1	223 b2	227 b3	223 b
400	230 c1	242 c3	240 c2	237 c

P_2O_5 lbs/a	K_2O lbs/a			Avg.
	100	200	300	
	- - - - - - - - - - K_2O removal, lbs/a - - - - - - - - - -			
100	168 a1	218 a2	249 a3	212 a
200	175 b1	226 b2	252 b3	218 b
300	174 b1	229 c2	256 c3	220 c

K_2O lbs/a	N, lbs/a			Avg.
	200	300	400	
	- - - - - - - - - - K_2O removal, lbs/a - - - - - - - - - -			
100	157 a1	176 a3	174 a2	172 a
200	201 b1	232 b2	240 b3	224 b
300	210 c1	261 c2	287 c3	253 c

Means with same letter within columns or same number within rows do not differ significantly at $P < .05$.

K_2O removal increased by 52 and 29 pounds per acre, respectively, as applied K_2O was increased from 100 to 200 and 300 pounds per acre. The magnitude of difference in K_2O removal was greatest among K_2O rates at the 400-pound N rate.

Calcium

Calcium (Ca) removal increased with increased applied N (Table 6). The average increase of Ca removal was 9 pounds per acre, approximately a 25 percent increase, as N applications increased from 200 to 400 pounds.

Applied P_2O_5 increased Ca removal by an average of one pound for each 100-pound increase in P_2O_5 over the 100-pound rate. However, Ca removal was lowered by 1 pound with each 100-pound increase in applied K_2O. Applied N influenced Ca removal to a much greater extent than did P_2O_5 or K_2O applications.

Average Ca removal of 30 and 39 pounds per acre annually represents an equivalent of 75 and 97 pounds of $CaCO_3$, respectively.

Magnesium

Mean effects of applied N, P_2O_5, and K_2O on magnesium (Mg) removal were significant (Table 7).

Table 6. — Mean effects of applied N, P_2O_5, and K_2O on Ca removal in Pensacola bahiagrass forage, 5-year average

N lbs/a	P_2O_5, lbs/a 100	200	300	Avg.
	- - - - - - - - - - Ca removal, lbs/a - - - - - - - - - -			
200	29 a1	30 a2	31 a3	30 a
300	35 b1	35 b1	37 b2	36 b
400	38 c1	39 c2	40 c3	39 c

P_2O_5 lbs/a	K_2O, lbs/a 100	300	300	Avg.
	- - - - - - - - - - Ca removal, lbs/a - - - - - - - - - -			
100	35 a3	33 a1	34 a2	34 a
200	36 b3	35 b2	34 a1	35 b
300	35 a1	37 c2	35 b1	36 c

K_2O lbs/a	N, lbs/a 200	300	400	Avg.
	- - - - - - - - - - Ca removal, lbs/a - - - - - - - - - -			
100	31 c1	38 b2	40 b3	36 c
200	30 b1	35 a2	40 b3	35 b
300	29 a1	35 a2	39 a3	34 a

Means with same letter within columns or same number within rows do not differ significantly at $P < .05$.

Mg removal was increased by 13 and 23 pounds when applied N was increased from 200 to 300 and 400 pounds per acre, respectively.

Applied P_2O_5 increased Mg removal on an average of one pound for each 100-pound increase of applied P_2O_5 above the 100-pound rate.

The effect of applied K_2O on lowering the Mg removal was of approximately the same magnitude as the effect that applied N had on increasing Mg removal.

Removal of 38 and 61 pounds of Mg represents the equivalent of 133 and 213 pounds of $MgCO_3$, or 158 and 254 pounds of $CaCO_3$, respectively.

Nutrient removal in the forage, when one or more of the three major plant nutrients was not applied, is shown in Table 8.

Of the nine selected fertilizer combinations, applied N had an overall greater effect on increasing nutrient removal than did applied P_2O_5 or K_2O. Nutrient removal in forage that received P_2O_5 and K_2O, alone or in combination, was essentially the same as that in the unfertilized forage.

There was considerable fluctuation in yearly nutrient removal as an average of all 36 treatments.

Table 7. — Mean effects of applied N, P_2O_5, and K_2O on Mg removal in Pensacola bahiagrass forage, 3-year average

N lbs/a	P_2O_5, lbs/a 100	 200	 300	Avg.
	- - - - - - - - - - Mg removal, lbs/a	- - - - - - - - - -		
200	38 a2	37 a1	38 a2	38 a
300	52 b2	52 b2	51 b1	51 b
400	59 c1	62 c2	63 c3	61 c
P_2O_5 lbs/a	**K_2O, lbs/a 100**	** 200**	** 300**	**Avg.**
	- - - - - - - - - - Mg removal, lbs/a	- - - - - - - - - -		
100	60 a3	47 a2	42 b1	49 a
200	61 b3	49 b2	40 a1	50 b
300	60 a3	49 b2	43 c1	51 c
K_2O lbs/a	**N, lbs/a 200**	** 300**	** 400**	**Avg.**
	- - - - - - - - - - Mg removal, lbs/a	- - - - - - - - - -		
100	44 c1	64 c2	73 c3	60 c
200	37 b1	48 b2	60 b3	48 b
300	32 a1	42 a2	51 a3	42 a

Means with same letter within columns or same number within rows do not differ significantly at $P < .05$.

Table 8.—Nutrient removal in Pensacola bahiagrass in response to selected fertilizer applications

Applied, lbs/a			Nutrient removal, lbs/a				
N	P_2O_5	K_2O	N	P_2O_5	K_2O	Ca	Mg[1]
0	0	0	55 ab	18 a	41 a	10 b	13 c
200	0	0	163 c	41 f	97 f	27 e	49 f
200	200	0	178 d	66 h	105 g	31 g	58 i
200	0	200	179 d	45 g	174 h	25 d	29 e
0	200	0	57 a	23 d	47 bc	11 c	14 d
0	0	200	59 b	19 b	56 d	10 b	12 b
0	200	200	54 a	21 c	49 c	9 a	10 a
300	0	0	181 e	39 e	91 e	27 e	52 g
400	0	0	201 f	41 f	98 f	28 f	53 h
Year effects, average of all treatments							
1967			220 b	72 c	238 e	37 d	
1968			173 a	53 a	125 a	28 b	
1969			172 a	55 b	169 b	27 a	36 a
1970			288 d	92 e	212 d	36 c	57 c
1971			255 c	76 d	173 c	28 b	45 b

[1] Three-year average.

Means with same letter in columns within groups are not significantly different at $P < .05$.

Efficiency of Utilization of Applied Nutrients

The removal of applied plant nutrients by the harvested forage is one measure of the efficiency of utilization of applied nutrients, when both forage yield and nutrient content are taken into account. Usually, the efficiency of utilization of a nutrient is determined by comparing the performance of the crop with and without that nutrient applied. Such comparisons aid in an economic evaluation of fertilization for forage production. Normally, a point is reached in forage production beyond which, although yield may continue to increase, the efficiency of utilization of the added nutrient decreases to the extent of being unprofitable.

The efficiency of utilization, expressed in percent, for each applied nutrient was calculated by the use of the following formula:

$$\frac{Ra - Rna}{A} \times 100 = E$$

Where: Ra = pounds of plant nutrient removed by the forage with that nutrient applied

Rna = pounds of plant nutrient removed by the forage without that nutrient applied

A = pounds of plant nutrient applied

E = percent efficiency of utilization of the plant nutrient applied

Nitrogen Utilization

Utilization of applied N is shown in Table 9. Percentage utilization of N declined uniformly from 75 percent with 200 pounds of applied N to 61 percent with 400 pounds. Thus, 400 pounds of N per acre were 14 percent less efficient than 200 pounds, and 7 percent less efficient than 300 pounds of N. The decrease in N efficiency with increased rates of applied N was consistent within the P_2O_5 rates tested.

Higher rates of P_2O_5 resulted in only a slight increase in the utilization of applied N. These increases probably are not economically significant.

N utilization was increased 4 percent with the application of 200 pounds of K_2O as compared to 100 pounds. Only 1 percent increase occurred when K_2O was increased from 200 to 300 pounds.

N utilization was maximized when 200 pounds of K_2O was applied in combination with 200 pounds of N. However, 300 pounds of K_2O was required for the highest utilization of both 300 and 400 pounds of N.

Phosphorus Utilization

Applied N exerted a considerable influence on the utilization of P_2O_5 (Table 10). As N rates were increased, utilization of P_2O_5 increased consistently at all levels of applied P_2O_5. Highest utilization of P_2O_5

Table 9.—Mean effects of applied N, P_2O_5, and K_2O on nitrogen utilization by bahiagrass, 5-year average

N lbs/a	P_2O_5, lbs/a 100	200	300	Avg.
	- - - - - - - - - - % Utilization of N		- - - - - - - - - -	
200	73	75	76	75
300	67	67	69	68
400	60	62	62	61
P_2O_5 lbs/a	**K_2O, lbs/a 100**	**200**	**300**	**Avg.**
	- - - - - - - - - - % Utilization of N		- - - - - - - - - -	
100	64	67	69	67
200	66	69	70	68
300	66	70	71	69
K_2O lbs/a	**N, lbs/a 200**	**300**	**400**	**Avg.**
	- - - - - - - - - - % Utilization of N		- - - - - - - - - -	
100	72	66	58	65
200	76	68	62	69
300	76	70	64	70

among N rates occurred in combination with 100 pounds of applied P_2O_5. However, P_2O_5 utilization was improved only slightly from additional N above the 300-pound level.

Phosphorus was most efficiently utilized when 100 pounds of P_2O_5 was applied per acre. A greater decline in utilization was observed when applied P_2O_5 was increased from 100 to 200 pounds than when it was increased from 200 to 300 pounds per acre. P_2O_5 applied at 300 pounds per acre was utilized less than half as efficiently as when applied at the 100-pound rate.

Applied K_2O had a rather modest effect on P_2O_5 utilization. The increase of P_2O_5 utilization due to increased rates of K_2O occurred mainly in combination with the 200- and 400-pound rates of N.

Potassium Utilization

Increasing applied N from 200 to 400 pounds per acre increased the average utilization of K_2O from 45 percent to 69 percent, or a total increase of 24 percent (Table 11). The increase was greater when N was increased from 200 to 300 pounds than when it was increased from 300 to 400 pounds per acre.

An average four percent increase in K_2O utilization resulted when applied P_2O_5 was increased from 100 to 200 pounds per acre. Increasing the P_2O_5 rate to 300 pounds did not increase the K_2O utilization.

Table 10.—Mean effects of applied N, P_2O_5, and K_2O on P_2O_5 utilization by bahiagrass, 5-year average

N lbs/a	P_2O_5, lbs/a 100	 200	 300	 Avg.
		% Utilization of P_2O_5		
200	22	14	10	15
300	33	20	15	23
400	35	21	16	24
P_2O_5 lbs/a	**K_2O, lbs/a 100**	**200**	**300**	**Avg.**
		% Utilization of P_2O_5		
100	29	30	31	30
200	17	19	19	18
300	13	15	14	14
K_2O lbs/a	**N, lbs/a 200**	**300**	**400**	**Avg.**
		% Utilization of P_2O_5		
100	15	23	22	20
200	17	23	23	21
300	22	22	27	24

An average decrease of 8 and 10 percent utilization of K_2O occurred as rates of applied K_2O were increased from 100 to 200 and 300 pounds, respectively. Utilization was lowest when 300 pounds of K_2O was applied in combination with 200 pounds of N. Highest utilization occurred with 100 pounds of K_2O and 400 pounds of N.

These data in Tables 9, 10, and 11 reflect the extent to which nutrient utilization can be altered, depending on both the rates and ratios of nutrients applied.

Soil Analyses

Chemical analyses of soil samples taken annually provide a basis for fertilizer recommendations. Improper rates or ratios of applied fertilizer may result in either a depletion or accumulation of one or more nutrients.

The plant nutrients are reported as extractable parts per million in the soil in their respective elemental forms. Only the applied nutrients that had significant effects on soil analysis values are reported.

Phosphorus

Extractable phosphorus (P) values are reported in Table 12. Within years, there was a rather consistent trend for extractable P to be lowered

Table 11.—Mean effects of applied N, P_2O_5, and K_2O on the K_2O utilization by bahiagrass, 5-year average

N lbs/a	P_2O_5, lbs/a 100	200	300	Avg.
	% Utilization of K_2O			
200	42	47	46	45
300	61	61	65	62
400	65	72	70	69
P_2O_5 lbs/a	**K_2O, lbs/a 100**	**200**	**300**	**Avg.**
	% Utilization of K_2O			
100	63	57	48	56
200	70	60	49	60
300	69	61	50	60
K_2O lbs/a	**N, lbs/a 200**	**300**	**400**	**Avg.**
	% Utilization of K_2O			
100	52	71	79	67
200	48	63	67	59
300	35	52	61	49

with increased rates of applied N. Extractable P generally increased among years at all levels of N and P_2O_5 tested from 1967 through 1969. With the exception of 1967, extractable P increased significantly each year with each increase in applied P_2O_5 above the 100-pound rate.

Lexington silt loam soil test values of 10 to 35 ppm are characterized as low, 35 to 70 as medium, and above 70 as high availability. Bahiagrass utilized as a hay crop and receiving annual applications of 100 pounds of P_2O_5 with adequate N and K_2O maintained extractable P in the medium range. Application of 200 pounds or more of P_2O_5 maintained the P in the high range.

Potassium

Extractable potassium (K) was affected by rate of applied N, as indicated in Table 13. Application of more than 200 pounds of N annually decreased the K in each of the 5 years. There was considerable variation in extractable K within N rates among years.

Application of more than 100 pounds of K_2O annually increased K significantly for all 5 years. In 1971, extractable K had declined to a level characterized as very low in soil where 100 pounds of K_2O had been applied annually. Extractable K was within the low range in soils where both 200 and 300 pounds of K_2O had been applied annually. These data indicate that as much as 300 pounds of K_2O applied annually per acre, under the conditions tested, will not maintain extractable K at a medium

Table 12.—Mean effects of applied N and P_2O_5 on extractable P in Pensacola bahiagrass sod

Year	N, lbs/a 200	N, lbs/a 300	N, lbs/a 400
	P, ppm		
1967	46 ab	43 a	42 a
1968	58 b	54 b	50 a
1969	129 dc	122 cd	177 c
1970	135 e	126 de	120 cd
1971	127 dc	120 cd	111 c

Year	P_2O_5, lbs/a 100	P_2O_5, lbs/a 200	P_2O_5, lbs/a 300
	P, ppm		
1967	35 a	45 b	51 b
1968	36 a	50 b	75 c
1969	68 c	120 d	181 e
1970	71 c	125 d	185 e
1971	54 b	118 d	186 e

Means with same letter do not differ significantly at $P < .05$.

Table 13.—Mean effects of applied N and K_2O on extractable K in Pensacola bahiagrass sod

Year	N, lbs/a		
	200	300	400
	K, ppm		
1967	111 e	102 e	98 e
1968	81 cd	67 bc	59 ab
1969	147 f	108 e	88 d
1970	109 e	86 d	73 c
1971	87 d	59 ab	52 a

Year	K_2O, lbs/a		
	100	200	300
	K, ppm		
1967	86 d	100 e	125 f
1968	54 b	67 c	86 d
1969	69 c	116 f	158 h
1970	51 ab	82 d	135 g
1971	42 a	65 c	92 de

Means with same letter do not differ significantly at $P < .05$.

level. Possibly, a combination of high uptake of K by the forage, the fixation of K by the soil, and some leaching of soluble K accounts for the low levels of extractable K.

Calcium

Extractable calcium (Ca), as influenced by N rate, is shown in Table 14. Extractable Ca generally increased at all N rates from 1967 through 1969. There were significant decreases in Ca from 1969 through 1971. The magnitude of decreases in Ca were larger as N rates were increased from 200 to 300 and 400 pounds per acre.

The removal of Ca by the harvested forage could account for probably 25 percent of the Ca removed from the 6-inch layer of soil tested. The single

Table 14.—Mean effects of applied N on extractable Ca in Pensacola bahiagrass sod

Year	N, lbs/a		
	200	300	400
	Ca, ppm		
1967	1,161 de	1,119 d	1,136 d
1968	1,290 g	1,222 ef	1,228 efg
1969	1,411 h	1,277 efg	1,224 efg
1970	1,148 d	1,071 c	1,020 bc
1971	1,071 c	991 ab	936 a

Means with same letter do not differ significantly at $P < .05$.

Table 15.—Mean effects of applied N on extractable Mg in Pensacola bahiagrass sod

Year	N, lbs/a 200	300	400
	Mg, ppm		
1967	345 e-h	333 d-f	343 e-h
1968	374 i	355 g-i	363 hi
1969	407 j	361 hi	352 f-h
1970	314 b-d	298 ab	284 a
1971	347 e-h	327 c-e	307 bc

Means with same letter do not differ significantly at $P < .05$.

largest loss was possibly due to leaching.

An extractable Ca level of 1,000 ppm or less is rated as low. Levels of from 1,000 to 1,300 are rated medium, and above 1,300 ppm are rated high.

Magnesium

There was considerable variation of extractable magnesium (Mg) in response to applied N (Table 15). No consistent trend of Mg levels occurred over years within the N rates. However, after 1968 Mg decreased with increased rates of N above 200 pounds per acre. In all cases extractable Mg values were in the high range.

Soil Reaction

Differences in soil reaction (pH) as related to rates of applied N were not evident until 1969 (Table 16). Thereafter, pH decreased more rapidly as N rates were increased from 200 through 400 pounds per acre. As an average, there was a 0.2 decrease in pH with each additional 100-pound increase of N over the last 3 years.

Possibly the applied limestone reacted and went into solution at a sufficient rate the first 2 years to offset both the acidifying effects of applied N and the losses of bases due to plant removal and leaching.

Table 16.—Mean effects of applied N on soil reaction in Pensacola bahiagrass sod

Year	N, lbs/a 200	300	400
	pH		
1967	7.0 i	7.0 i	7.0 i
1968	6.9 h	6.9 h	6.9 h
1969	6.8 g	6.6 f	6.4 e
1970	6.4 e	6.2 d	6.0 c
1971	6.2 d	5.9 b	5.7 a

Means with same letter do not differ significantly at $P < .05$.

SUMMARY AND CONCLUSIONS

Significant dry forage yield increases of bahiagrass were obtained from applications of up to 400 pounds of N per acre and from up to 300 pounds of both P_2O_5 and K_2O. Yield responses were greatest to applied N, followed by applied K_2O and P_2O_5. Yield increased from 10,691 pounds per acre at the 200-pound N rate to 12,797 and 13,970 pounds with 300 and 400 pounds of N, respectively.

Yield increases from the application of more than 100 pounds of P_2O_5 do not appear to be justified economically, although they are statistically significant.

Yields increased by about 500 pounds per acre with each increase in applied K_2O above the 100-pound rate. Fertilizer combinations that appeared to be most practical were: 100 pounds each of P_2O_5 and K_2O with either 200 or 300 pounds of N; 100 pounds of P_2O_5 and 200 pounds of K_2O with 400 pounds of N. Forage yield without any applied fertilizer was approximately 3,400 pounds per acre.

Distribution of forage yield throughout the season was not affected as much by applied plant nutrients as was total yield. Dry matter production increased from May to late July and then declined until mid-October. Forage production was slightly less at the end of the season than at the beginning.

Crude protein content was increased by about 1 percentage unit, as an average over the season, for each increase in applied N above the 200-pound rate. Protein decreased approximately 6 percentage units (from approximately 19 percent to 13 percent) from May to late June but then showed a tendency to increase during the remainder of the season.

Phosphorus content of the forage was increased throughout the season with increased rates of applied P_2O_5. Within the season, forage P declined rapidly in May and June and then increased slightly until early October.

Potassium content of the forage was increased by higher rates of applied K_2O. However, K content declined throughout the season regardless of amount of K_2O applied.

Calcium and magnesium contents were lowered by applications of K_2O, and increased, to a lesser extent, by N applications. Both Ca and Mg content decreased in the early part of the growing season and increased for the remainder of the season.

Cell wall constituents, ADF, and in vitro DDM were affected only slightly by fertilizer treatments. CWC and ADF increased sharply in May and June, with a tendency to decline thereafter. The decrease of about 12 percentage units in DDM from May to July coincides with the period that bahiagrass produces seedheads most profusely.

Approximately 50 additional pounds of N were removed in the harvested forage with each 100-pound increase in applied N above the 200-pound rate.

Removal of P_2O_5 was increased from 75 to 87 pounds as applied P_2O_5 was increased from 100 to 300 pounds per acre.

Removal of K_2O was increased from 172 to 253 pounds as applied K_2O was increased from 100 to 300 pounds per acre.

Applied N had greater effects on calcium and magnesium removal than did applied K_2O. Increasing N rates from 200 to 400 pounds increased Ca removal from 30 to 39 pounds and Mg from 38 to 61 pounds.

Utilization of applied N declined from 75 percent at the 200-pound rate to 61 percent at the 400-pound rate. Applied P_2O_5 utilization dropped from 30 to 14 percent as the applied rates were increased from 100 to 300 pounds per acre.

Average utilization of K_2O decreased from 67 to 49 percent when applied K_2O was increased from 100 to 300 pounds per acre. However, increasing N rates from 200 to 400 pounds increased K_2O utilization from 45 to 69 percent.

Extractable P increased significantly the third, fourth, and fifth year in response to P_2O_5 applications.

Increased rates of applied K_2O increased significantly the levels of extractable K. Extractable K was rated low in availability in plots that received 300 pounds of K_2O per acre after five continuous years of cropping.

Extractable Ca and Mg were lowered more rapidly as N rates were increased from 200 to 400 pounds. This negative relationship between extractable Ca and Mg and applied N was most pronounced during the last three years of the study.

Soil reaction (pH) was decreased numerically by 0.2 with each additional increase in applied N above the 200-pound rate each year beginning in 1969 and continuing through 1971.

These data substantiate that forage yield, protein, and mineral contents were altered significantly by varying both the rates and ratios of N, P_2O_5, and K_2O applied to bahiagrass. Also affected were amounts of nutrients removed by harvested forage and efficiency of utilization of the applied plant nutrients. Generally, seasonal effects altered seasonal distribution of the various forage measurements more than did fertilizer treatments. Bahiagrass forage of highest quality was produced in May and June. Fertilizer application did not have any appreciable effect on the in vitro measurements of forage quality.

Literature Cited

1. Allen, G. C., E. F. Hodges, and M. Devers. 1972. National and state livestock-feed relationships. ERS, USDA State Bul. Suppl. 446.
2. Allen, Marvin. 1976. Comparison of growth characteristics and forage quality estimates of six perennial grasses. Ph.D. dissertation. Miss. State Univ., State College, Miss.
3. Allen, Marvin, H. D. Ellzey, B. D. Nelson, C. R. Montgomery, and P. E. Schilling. 1974. The response of an oat-ryegrass mixture to applied nitrogen, phosphorus, and potassium. La. Agri. Exp. Sta. Bul. 680.
4. Association of Official Agricultural Chemists. 1960. Official methods of analysis. 9th ed. Washington, D. C.
5. Brouwer, E. 1961. Mineral relationships of the ruminant. *Digestive Physiology and Nutrition of the Ruminant.* Butterworth, Inc., Washington, D. C.
6. Brupbacher, R. H., W. P. Bonner, and J. E. Sedberry, Jr. 1968. Analytical methods and procedures used in the soil testing laboratory. La. Agri. Exp. Sta. Bul. 632.
7. Garmans, W. H., D. A. Williams, H. N. Hunsicker, and L. H. Davis. 1967. Our land and its care. 4th ed., (pp. 24-25). Plant Food Inst., 1700 K St., N. W., Washington, D.C.
8. Lowrey, R. S. 1969. The nylon bag technique for the estimation of forage quality. National Conf. on Forage Quality Evaluation and Utilization, 0-1-12. Lincoln, Neb.
9. National Academy of Sciences, National Research Council. 1966. Nutrient requirements of ruminants. No. 3, 3rd ed. Publ. 1349. Washington, D.C.
10. Scott, J. M. 1920. Bahiagrass. J. Amer. Soc. Agron. 13:112-114.
11. Snedecor, G. W., and W. G. Cochran. 1967. *Statistical Methods.* 6th ed. Iowa State Press, Ames, Iowa.
12. Van Soest, P. J., R. H. Wine, and L. A. Moore. 1966. Estimation of true digestibility of forage by the in vitro digestion of cell walls. Proc. X Int. Grassland Congr., Helsinki, Finland.
13. Ward, C. Y., and V. H. Watson. 1973. Bahiagrass and carpetgrass. *Forages.* 3rd ed., (pp. 314-318). The Iowa State Univ. Press, Ames, Iowa.

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RED CLOVER BREEDING n Louisiana

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ulletin 702 June 1977

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Red Clover Breeding in Louisiana

C. R. Owen

Introduction

Red clover (*Trifolium pratense* L.) has not been grown extensively in Louisiana, but has had limited use, primarily as a pasture and hay crop. Those who have grown it have been generally pleased with its performance. Red clover has been grown in areas north of Tennessee and Virginia for many years because most varieties and strains developed in the past have been acclimated to such a region. Field trials have shown that such varieties and strains have not generally been adapted to environmental conditions farther south. This crop is best adapted to the heavier soil types. Fertility requirements of red clover are similar to those of white clover, and perhaps not so exacting as those of alfalfa. The nutritive value of red clover approaches that of alfalfa. Objections have been raised by some that red clover hay does not have a green color. This loss of color, thought to be due to an enzyme present in the leaves, does not affect the palatability or nutritive value of the hay.

In past years, red clover varieties have been developed by the influence of local conditions rather than by any formal breeding practices (*12*)[2]. There are varieties and strains that developed in the southern region by becoming acclimated to the area. These were found to be high producers of forage, but were lacking in resistance to foliage diseases, especially powdery mildew (*Erysiphe polygoni* D.C.). This disease, while not a serious hazard to the production of this crop for pasturing animals, is considered highly objectionable when clover is cut for hay. This fungus is present on mature leaflets, and under grazing a large portion of the leaves are consumed prior to maturity.

A breeding program was initiated with red clover in 1945 to develop improved varieties adapted to Louisiana. The principal objectives were to develop varieties that would produce high forage yields and be resistant to foliage diseases. Adapted varieties of this crop could add substantially to the quality of the forage produced in the state and to the economical production of livestock.

Most varieties of red clover observed in space plantings in nurseries were found to be variable for powdery mildew infection. This afforded an opportunity to develop disease-resistant strains. It was realized that such strains should be developed from acclimated stock to be of greater value for use in Louisiana. Red clover is classed as a perennial by botanists

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[2] Italic numbers in parentheses refer to Literature Cited, Page 16.

and behaves as such in the Midwest and in northern states. In Louisiana, in most years, it may be considered an annual. Consequently, seed-increase fields have been forced to reseed naturally, thereby developing the hard-seed characteristic within the variety Tensas.

Review of Literature

In the wild state, red clover ranges over most of Europe and far into Siberia (*12*). Pieters and Hollowell (*12*) said "the crop was known to be generally cultivated in the Netherlands 370 years ago and possibly there may have been an older culture of clover." The wild red clover is an extremely variable species. There are early, late, smooth, hairy, prostrate, erect, and semi-erect forms (*12*).

The many varieties that developed prior to about 1937, according to Pieters and Hollowell (*12*), were developed by action of local conditions rather than by conscious selection and testing. Nothing is definitely known, they stated, regarding the origin of the red clover now common to North America, with its hirsute or hairy leaves and stems.

Many varieties were known to be in existence prior to about 1940. These arose from strains that developed by natural means. Farmers usually recognized these as superior and kept them pure by natural isolation. Among such varieties were Nolin's in Louisiana and Port Gibson in Mississippi (*11*). Chesapeake red clover was found growing in an area of Maryland, and the seed found their way into market channels (*4*). Among the varieties developed by a formal breeding program were Tensas (*11*), Kenland, and Kenstar (*14*).

The genetics of red clover was reviewed by Attwood (*3*). He stated that the chromosome number of red clover was N = 14. The relationship of the fertility factor was of the diploid personate type of multiple oppositional alleles. The number of factors for sterility was considered to be extensive (*3*).

The factor S (for sterility) was shown by Williams (*21*) to be located on linkage group 2, where it was linked with the factor C/c for flower color. The mean cross-over value for S and C was found to be about 35 (*21*). Seven simple recessive factors governing the production of yellow chlorophyll-deficient seedlings were reported by Williams (*19*). These were reported as being different from each other and from all of the eight white seedling factors also reported by Williams (*18*). Williams (*20*), reporting on the genetics of red clover and its bearing on practical breeding, referred to the extensive series of factors for sterility. Twenty plants, which were studied for sterility constitution, were found to carry 34 different sterility alleles. He further stated that, from the standpoint of plant improvement, self-fertility was undesirable. Inbreeding invariably resulted in a marked and progressive loss of vigor.

Rinke and Johnson (*13*) reported a self-fertile clone of red clover. It continued to be highly self-fertile in 10 subsequent generations. A method was outlined for the use of the self-fertile clone in a breeding program.

Williams and Williams (*17*) reported on the employment of the pseudo-self-fertility factor for producing selfed seed from the self-incompatible clones. Four homozygous genotypes were produced by the utilization of this factor present in certain lines. Leffel (*8*) reported on the use of the pseudo-self-fertility factor in the production of selfed seed in clones known to be self-incompatible. He stated that the degree of pseudo-self-compatibility (PSC) varied at different dates of determination, but clonal differences for this factor were generally consistent. Relatively high temperatures (90° F), he said, increased pseudo-self-compatibility of the four selected clones. Leffel and Muntjan (*7*) subjected clones of randomly selected red clover plants to various treatments suggested in the literature as affecting PSC. They reported that PSC was a definite clonal characteristic. Virus diseases, gibberellic acid, and wilting did not alter its expression.

The effects of maternal line selection for persistence were reported by Mokhtarzadeh, et al. (*10*). Anderson, et al., (*1*) discussed combining ability of open-pollinated clones of red clover. Anderson and Kirthavip (*2*), reporting on the development and performance of hybrid red clover, said most hybrids were not superior to the best check varieties. Taylor, et al., (*15*) discussed the results of inbreeding and heterosis. They failed to report specific gains from hybrids between inbred parents.

Nitrogen fixation by red clover was reported by Lyon and Bizzel (*9*). They included red clover in the earliest report on the benefits of growing legumes with oats. Other legumes included were alfalfa and winter peas. It was found that the protein content of the forage was increased when oats and timothy were grown with any of these legumes. Harlan (*6*) reported red clover grown in Finland produced a large amount of nitrogen.

Powdery mildew was described by Dickson (*5*) as an obligate parasite persisting on the foliage of red clover in moderate climates and apparently spreading rapidly late in the summer. The control, stated Dickson, was chiefly through use of resistant varieties.

Materials and Methods

Breeding Methods

The objective in breeding red clover was to develop superior types, strains, or varieties suited for growing in Louisiana and the South. At the time this research was initiated there were acclimated varieties growing within the state. Although they were productive, they lacked resistance to certain diseases prevalent in the area, especially powdery mildew.

During the summer of 1945, seed were procured from each of the acclimated strains, as well as from other red clover varieties grown in Louisiana. These were established in a space-planted field nursery by germinating the seed in the greenhouse, transferring the seedlings to

6-ounce paper cups filled with soil, and finally transplanting them to the field during April. About 2,500 seedlings were established. Selections were made from the plants that had survived the summer in thrifty condition and were relatively free of disease during late summer. Seed from these selected plants were planted in progeny row tests the following fall. Seed from the better progenies were carried forward to new strain experiments. Finally, seed from five of the most outstanding new strains were planted in adjacent rows in an isolated area and allowed to interpollinate. The seed from these strains were mixed and designated as Louisiana Strain 1.

Seed of Strain 1 were planted in a seed increase block and grown for a number of seasons. Seed were harvested each year and used for planting in yield trials and for conducting demonstrations. The clover was forced to reseed on the land each year.

This strain of red clover was found to excel in forage production, and it had less powdery mildew than the other varieties tested, yet during most seasons it had more powdery mildew infection than was desirable for good quality hay.

After the test period, Louisiana Strain 1 was given the variety name "Tensas." The lines from which it was formed were derived from seed that came from a farm in Tensas Parish.

Breeding for Resistance to Powdery Mildew

The program for developing strains of Tensas with resistance to powdery mildew was begun in 1958. The screening was started in the greenhouse, but it was found that even in the presence of mature plants that were infected with the disease, no discernible infection was visible on the seedlings. After two or three trials it was concluded that the greenhouse facilities were not suited for the work. It was thought that the temperature became too high in the greenhouse early in the season. Consequently, it was necessary to use field nurseries. A planting of several hundred plants, spaced three and one-half feet apart, was made in the fall. These were thinned to one plant per hill the following spring. When the plants had matured seed, individuals were selected that were free of the disease.

Progeny rows were established in a spaced nursery with seed from the selected plants. The seed were planted in hills spaced three and one-half feet apart in rows of the same width. Plants were thinned to one plant per hill the following spring. When the blossoming had begun, each plant was marked with a dated stake. After the beginning of the season for blooming, the nursery was observed daily until all of the plants had bloomed.

After the blossoming stage and when plants were near the mature stage, each plant was scored for powdery mildew infection (score of 0 to 10 for mildew-free to full cover of the leaves with the disease), and each was scored for size (0 to 15 for small to large). Mildew-infected plants were removed from the nursery and destroyed. Mildew-free plants were cut back and new growth was allowed to arise from the crowns. The seed that were born on the regrowth from disease-free plants were harvested. The basis for making selections was vigor of the regrowths and the amount of seed produced. These progeny tests were repeated each year until the susceptible segregates were reduced to a minimum. The time was prolonged as a result of light infection some seasons and no infection at all during certain years.

In another area of the experimental field, isolated from the progeny nursery, similar experiments were conducted with certain varieties, including those known to be resistant to the disease and others known to be susceptible. The results from these tests were used as an indication of the prevalence of the disease spores. Forage yield trials were also conducted each year, and checks were made on the yields of entries formed from massed seed from the selected plants.

Experiments also were conducted to compare the forage production of red clover and white clover. Plots were seeded in the fall and forage was harvested the following April, May, and June. New plantings were made each year for these comparisons.

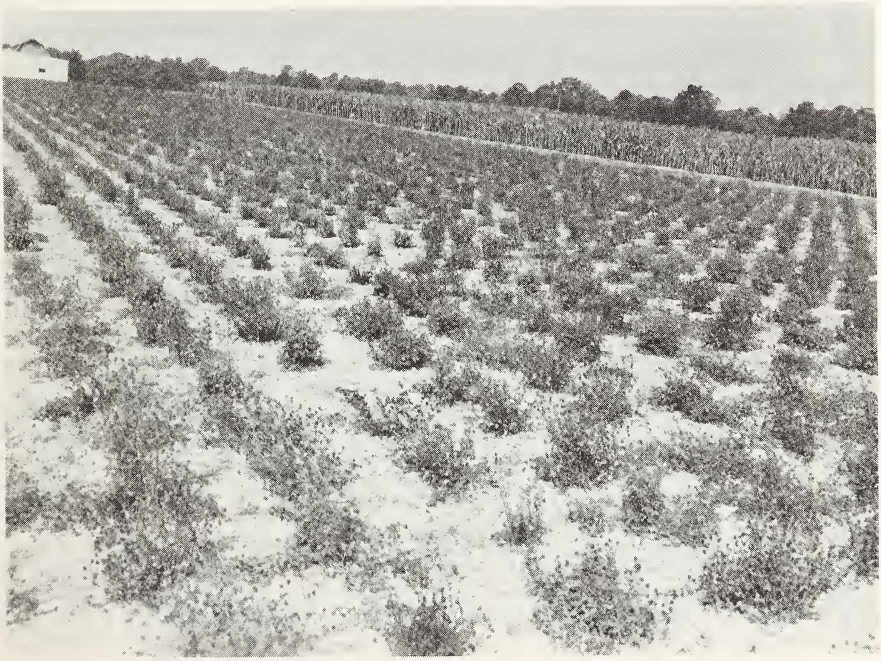

Figure 1.—Spaced nursery with mature plants.

Observations were made of the seed setting of varieties as well as of seed production and seed harvesting of the improved strains.

Results

The results from recurrent selection for powdery mildew resistance are shown in Table 1 for the years 1963 through 1972. These data were taken from progenies beginning the fourth generation after the program was started. The data show that in 1963 only four progenies out of 70 had no plants showing powdery mildew infection at full bloom. The mean score value for the entire nursery was 0.67. In 1964 there were 32 progenies that had no plants showing the disease at the stage of growth in which they were scored. The average score for all progenies was 0.30. In 1965, on the other hand, progenies of disease-free selections made from among the plants of the nursery in 1964, produced no progenies that were scored as being free of mildew. In fact, the infection was excessively high. Certain of the progenies were scored to be fully covered with mildew. The average for all progenies was 3.81. The difference in infection for the two seasons from practically the same genotypes was likely due to weather conditions or a different race of the disease organism.

The score data for the progenies the following year, 1966, showed an improvement but were still higher than for the other seasons during which the experiments were conducted. In 1969 there was very little infection from the disease.

Data in 1970 showed that of 100 progenies, not one was found to be infected. In 1971 only six of the total of 60 progenies were free of the disease. Infection was light, but there was some fungus present on many of the plants. Infection was also light in 1972; there were 16 progenies in

Table 1.—Distribution of progenies of red clover by classes of infection with powdery mildew

	Infection classes*											
Year	0	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	Mean
	Number of progenies in each infection class											
1963	4	55	10	0	0	1	0	0	0	0	0	0.67
1964	32	48	0	0	0	0	0	0	0	0	0	0.30
1965	0	1	8	16	12	12	7	3	1	2	1	3.81
1966	7	36	15	6	3	1	2	0	0	0	0	1.16
1967	21	36	6	3	0	0	0	0	0	0	0	0.23
1969	65	1	0	0	0	0	0	0	0	0	0	0.01
1970	100	0	0	0	0	0	0	0	0	0	0	0.00
1971	6	41	12	1	0	1	0	0	0	0	0	0.71
1972	16	43	1	0	0	0	0	0	0	0	0	0.38

*Score values: 0 = no powdery mildew infection; 10 = full cover of leaflets with mildew. Scores are based on class centers.

which none of the plants was found to be infected at the full bloom stage. For those plants infected with the fungus, the scores amounted to less than 1.0. This should be considered as only a trace. The average score for 60 progenies in 1972 was 0.38. Score values were obtained from the average score for the plants in each progeny row at approximately full bloom. The average for the nursery included the mean infection score from all of the rows.

Tests using representatives of commercial varieties were conducted each year. Data from these experiments were used as an indication of the presence of the disease each season. Seed of these varieties were planted in spaced hills and managed in the same way as that of the progeny nursery. The tests were replicated and isolated from the progeny nursery.

Results shown in Table 2 indicate considerable variation from year to year in score values for disease infection. Inasmuch as infection was exceedingly light on the varieties in some years and heavy in others, it was assumed that the presence of an epidemic from year to year was uncertain and probably associated with fluctuations in weather conditions.

Powdery mildew is an obligate parasite (5), as the disease persists only in the presence of the host plants. Since the acreage of red clover is very small in Louisiana, the probability of obtaining an epidemic year after year is lessened in natural field plantings. Absence of mildew in 1964 and the presence of it to a considerable extent in 1965 might be attributed to a change in weather conditions. Mildew was present on the varieties in 1967 and 1968, but the varieties were less affected in 1969 and 1970.

Powdery mildew infection has not been a factor that would exclude the growth of red clover in south Louisiana during certain seasons. However, during years when infection prevails, plots planted to susceptible varieties have been almost entirely covered by the disease and the quality of forage has been reduced.

Table 2.—Varieties and strains of red clover compared for infection from powdery mildew, 1965-70

Variety or strain	1964	1965	1967	1968	1969	1970
	Powdery mildew infection score*					
Orbit	0	1.21	0.10	0.70	0.12	0
Tensas	0	2.60	0.42	0.78	0.12	0
Tensas, foundation seed	0	3.92	1.10	1.50	0.13	0
Tensas, parent	0	6.59	4.80	4.60	0.17	0.05
Kenland	0	—	—	—	0.83	0.28
Nolin's	0	8.57	—	5.60	0.09	0.06
LSD (5%)	—	0.97	1.35	1.51	—	—

*0 = no infection; 10 = fully covered with mildew.

Table 3.—Red clover strains developed from Tensas compared with the parent variety for powdery mildew infection, length of growing season, and dry weight of plants

Strains	Powdery mildew infection score*	Length of growing season, days	Dry weight of plants, pounds
Tensas, parent	4.80	162	0.61
Tensas, foundation seed	1.10	171	0.86
Tensas, breeder seed	1.10	172	1.30
Orbit	0.10	187	0.75
Massed seed of selected plants in 1965	0.17	173	1.00
Massed seed of selected plants in 1966	0.42	176	0.94
LSD (5%)	1.35	3.0	0.19

*0 = no infection; 10 = fully covered with mildew.

Comparison of New Strains with the Parent Variety and Orbit for Powdery Mildew Infection

During the 1967 season an experiment was conducted at Baton Rouge to compare new strains formed by the massing of the seed of a portion of the plant selections for 1965 and 1966. This experiment was conducted in a manner similar to that used with the progeny rows. It was,

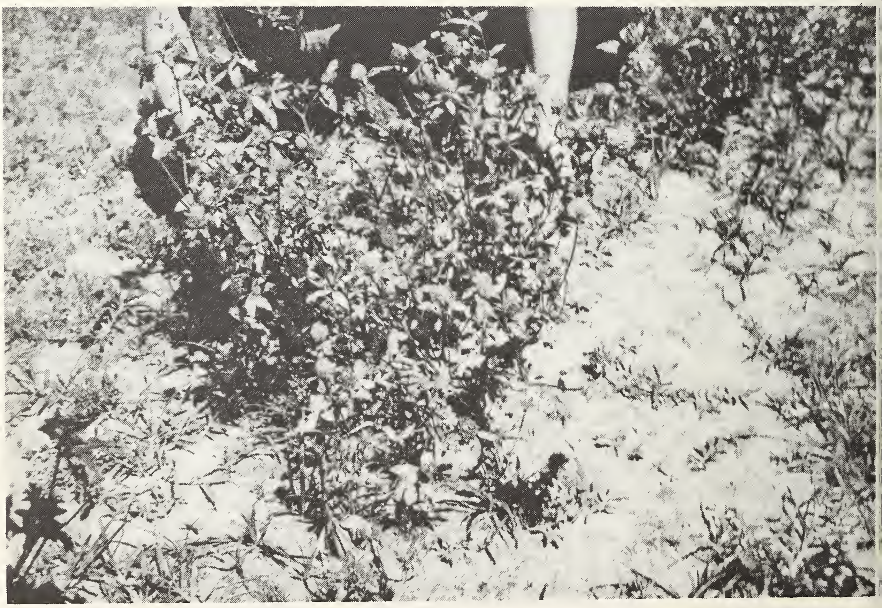

Figure 2.—Single plant infected with powdery mildew.

however, planted in an area isolated from the progeny nursery.

The results from these experiments are shown in Table 3. Powdery mildew infection on the parent strain was moderate. Foundation seed produced plants with significantly less infection than the parent strain. Breeder seed produced plants that had the same score value as the foundation class. Orbit, which has more resistance to the disease than any of the other varieties and strains tested, had the lowest score. But the difference between Orbit and the entries formed by massing selected seed of mildew-free plants from the progenies selected from Tensas was not significant. The plants from the massed seed of the selected plants from progenies from 1965 and 1966 had lower scores for powdery mildew infection than plants from breeder or foundation seed, but they were not significantly lower at the 5 percent level of probability than those of Orbit. The fact that the scores for mildew were less from the new strains than from the plants from breeder seed or foundation seed indicated some progress. Specific studies were not made of the inheritance of resistance/susceptibility to powdery mildew. Observation led to the assumption that factors for resistance were dominant, but no further conclusions could be drawn.

Length of growing season was found to differ among strains and varieties. Strains developed from Tensas were later in maturing than the parent. Orbit was more than 3 weeks later in maturing than the parent, Tensas. The

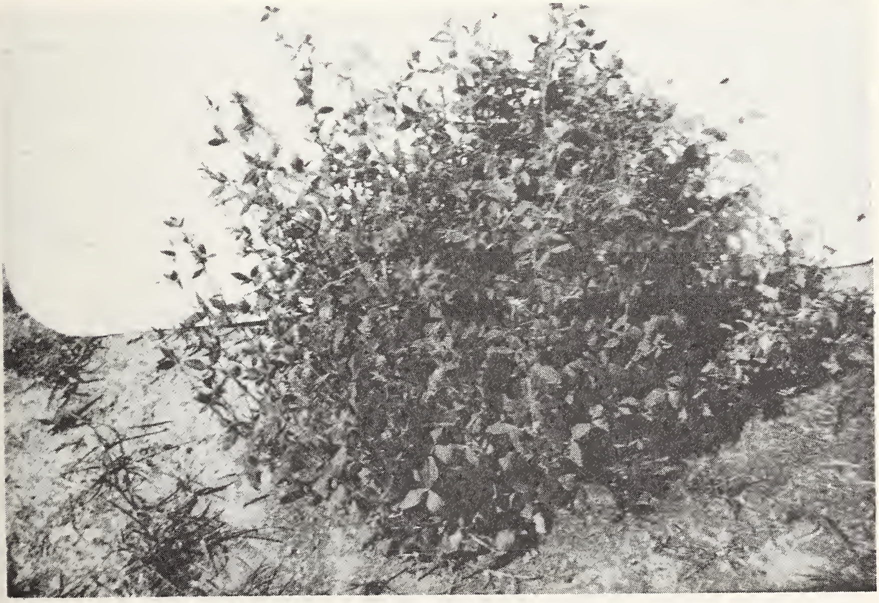

Figure 3.—Single plant free of powdery mildew.

other entries, which were derived from the parent, were 10 to 15 days later than the parent strain. It may be thought that the stage of maturity affected the scoring. However, scoring was done for each entry when the plants had passed the full bloom stage so that they were at practically the same stage of maturity.

The average weight of plants produced by the different strains and varieties differed significantly. However, this has varied from season to season. In most years, the late plants produced more dry matter than those that matured early. It was not necessarily true, however, that strains which produced the large plants when space-planted gave high yields when sown in solid stands.

The new strains, which were evaluated for forage yields, mildew resistance, blooming date, and other characteristics, were transitional. That is, they were formed from a composite of plants selected from the progeny nurseries. This practice was repeated every second or third year during the period this work was underway.

Forage Yields of Varieties and New Strains

Forage yield trials were conducted each year during the time the breeding program was conducted. The new strains designated as breeder and foundation strains in Table 4 were evaluated for forage production by planting them in replicated yield trials with certain standard varieties, also given in Table 4.

It was the practice in the breeding program to form new strains from the selected plants every other year. Hence, the new strains planted in the yield trials in 1970 and 1971 were different from those planted in previous years.

Forage production of breeder and foundation seed was significantly less than that of the parent variety during the first 3 years, as shown in Table 4. However, during the last 2 years and for the average for the 5 years, the differences were not significant.

Emphasis was given to selection of plants that were free of powdery

Table 4.—Forage yields of varieties and strains of red clover on Olivier silt loam, Baton Rouge

Variety or strain	1966	1967	1968	1970	1971	Average
	Pounds hay per acre					
Tensas, parent	8,272	8,888	10,637	12,595	9,949	10,068
Nolin's	7,275	9,118	10,458	10,809	9,389	9,410
Chesapeake	—	—	8,883	9,972	9,070	9,308
Tensas, foundation	6,697	8,215	9,676	10,861	8,677	8,825
Kenland	7,924	8,417	8,999	9,940	8,645	8,785
Tensas, breeder	7,394	7,734	9,701	10,118	8,645	8,718
Orbit	7,063	7,908	8,742	10,861	8,383	8,591
LSD (5%)	1,066	627	413	NS	NS	NS

mildew during the entire time the breeding program was underway. Obviously, not all plants that showed resistance to this foliage disease excelled in forage vigor. This was recognized early in the program. Plants in the nursery showed sufficient variation for use in increasing forage production in the ensuing strains. The results from the forage yield trials show that the performance of the new strains improved in 1970 and 1971 in comparison with the standard varieties.

Forage Yields of Red Clover and White Clover

Comparisons were made of the forage yields of Tensas red clover and Louisiana S-1 white clover during the years 1964 through 1972, with the exception of 1968 when no test was conducted. The forage harvests were made in April, May, and June. Differences that were statistically significant in favor of red clover were found in the total annual yields for 5 of the 7 years the results were recorded (Table 5).

Red clover is better adapted for the production of hay than is white clover. Forage harvests were made of both species at monthly intervals and one harvest was made at full bloom. Forage production from red clover was greater when only one harvest was made at full bloom than when harvests were made at intervals. The total yield of white clover was larger when the forage was harvested at monthly intervals.

The nutritive value of red clover was found to be less than that of white clover, but was equal to that of alfalfa and certain other forage legumes.

Table 5.—Forage yields of red clover and white clover on Olivier silt loam, Baton Rouge

	April		May		June		Total annual yield	
Year	Red clover	White clover	Red clover	White clover	Red clover	White clover	Red clover	White clover
	Pounds hay per acre							
1 1964	2,245*	1,701*	1,769	1,659	2,688*	1,516*	6,702*	4,876*
2 1965	3,504	3,184	977	687	1,400*	612*	5,581*	4,483*
3 1966	3,072*	1,892*	1,804	2,198	2,377	1,674	7,253*	5,764*
4 1967	4,642	3,695	2,105	2,820	1,461	1,547	8,208	8,062
5 1969	3,235	3,305	2,545	2,314	1,187	1,060	6,967	6,679
6 1970	4,476*	4,164*	3,132	3,189	1,808*	857*	9,416*	8,210*
7 1972	5,246*	3,961*	2,800*	1,372*	929	699*	8,975*	6,032*
Average	3,774	3,129	2,162	2,034	1,693	1,391	7,629	6,301

*Differences between white clover and red clover for yield of hay in pounds per acre significant at the 5% level of probability for corresponding harvest dates.

Seed Production

Seed production by red clover has been investigated during the breeding program. It is similar to white clover in that insect pollinators are necessary for seed formation. The most effective pollinator is the bumble bee. However, with sizeable acreage and the cultural habits on most farms, it is unlikely that the natural population of bumble bees will be sufficient for effective seed set. Hives of honeybees may be supplied to serve as additional pollinators. The number of hives necessary for successful seed set will vary, but it is thought by some workers that one strong hive per acre should be adequate.

Seed production, harvesting, and cleaning are similar to that of white clover. Seed yields may vary with seasonal conditions during the growing season and the type of soil. A moderate yield of seed would be 150 to 200 pounds per acre. Yields of 400 pounds have been harvested in Louisiana.

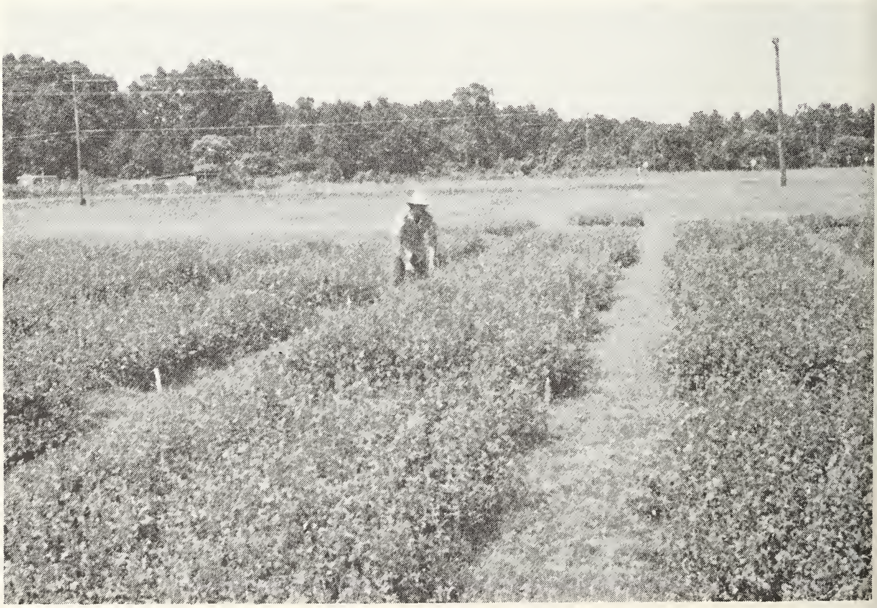

Figure 4.—Variety yield experiment at harvest stage.

Summary

An acclimated variety of red clover was developed for use in Louisiana that was more productive than varieties developed in areas farther north.

The variety was developed from plant selections taken from seed sources found in Louisiana. The selections were tested in progeny plots; this testing was followed by new strain tests. Five outstanding lines were combined to form ''Tensas,'' a variety name given for Tensas Parish, the place of origin of the seed from which the selections were taken.

Resistance to the disease powdery mildew, (*Erysiphe polygoni* D. C.), was established by recurrent selection for mildew-free plants made after the full-bloom stage. Blossoms and seed heads were removed from mildew-free plants, and they were forced to form seed on the second growth from the crown. The mildew-infected plants were removed from the nursery and destroyed. Selections were made from the second growth based upon vegetative vigor and seed production.

Powdery mildew infection varied in severity from year to year. It was severe during certain years, but in other years only traces could be found. This was verified by growing susceptible varieties.

Forage yields of red clover exceeded the yields of white clover significantly in 5 of the 7 years the comparative tests were conducted.

Literature Cited

1. Anderson, M. K., N. L. Taylor and R. P. Hill, Jr. 1974. Combining ability of I_0 single crosses of red clover. Crop Sci. 14:417-419.
2. ——— and R. Kirthavip, 1972. Development and performance of double-cross hybrid red clover. Crop Sci. 12:240-242.
3. Attwood, S. S. 1947. Cytogenetics and breeding of forage crops. Adv. in Genetics. 1:48-52.
4. Decker, A. N., Jr., R. C. Leffel, C. P. Ellington, J. L. Newcomer and R. E. Wagner. 1957. Chesapeake: A new red clover variety. Bull. 462. Agr. Exp. Sta. Univ. of Md.
5. Dickson, J. B. 1947. Powdery mildew (*Erysiphe polygoni* D. C.). Diseases of field crops. McGraw-Hill Book Co. New York. 317-318.
6. Harlan, Jack R. 1956. Theory and dynamics of grassland agriculture. D. Van Nostrand, Princeton, New Jersey. 91-94.
7. Leffel, R. C. and A. L. Muntjan. 1970. Pseudo-self-compatibility in red clover (*Trifolium pratense* L.). Crop Sci. 10:655-658.
8. Leffel, R. C. 1963. Pseudo-self-compatibility and segregation of gametophytic self-incompatible allels in red clover, (*Trifolium pratense* L.). Crop Sci. 3:377-380.
9. Lyon, T. L. and J. A. Bizzel. 1911. A heretofore unnoticed benefit from the growth of legumes. Bull. 204. Cornell Univ. Agr. Exp. Sta. 365-374.
10. Mokhtarzadeh, A., R. C. Leffel and E. A. Boyer. 1967. Maternal line selection for persistence in red clover, (*Trifolium pratense* L.). Crop Sci. 7:264-266.
11. Owen, C. R. and C. L. Mondart, Jr. 1963. Tensas: A red clover for Louisiana. La. Agr. 7:8, 9, and 15.
12. Pieters, A. J. and E. A. Hollowell. 1937. Clover improvement. Yearb. U. S. Dept. of Agriculture. 1190-1201.
13. Rinke, E. A. and I. J. Johnson. 1941. Self-fertility of red clover in Minnesota. J. Amer. Soc. Agron. 33:517-521.
14. Taylor, N. L. and M. K. Anderson. 1973. Kenstar red clover. Ky. Agr. Exp. Sta. Agr. 24. 3 pp.
15. ———, Karl Johnson, M. K. Anderson and J. C. Williams. 1970. Inbreeding and heterosis in red clover. Crop. Sci. 10:522-525.
16. ———, Eugene Dade and C. S. Garrison. 1966. Factors involved in seed production of red clover clones and their polycross progenies at two diverse locations. Crop Sci. 6:535-538.
17. Williams, R. D. and Watkin Williams. 1947. Genetics of red clover (*Trifolium pratense* L.) compatibility. II. a) Homozygous self-sterile SxSx genotypes obtained as a result of pseudo-fertility; b) Self-fertility. J. Genetics. 48:51-68.
18. ———. 1939. Genetics of chlorophyll deficiency in red clover (*Trifolium pratense* L.): Albinos. J. Genetics. 37:441-458.
19. ———. 1939. Genetics of chlorophyll deficiency yellow seedling factor. J. Genetics. 37:459-482.
20. ———. 1937. Genetics of red clover and its bearing on practical breeding. Proc. 4th Intn. Grassland Congress. 238-251.
21. ———. 1935. Genetics of flower color in red clover. (*Trifolium pratense* L.). J. Genetics. 31:431-450.
22. ———, and R. A. Silow. 1933. Genetics of red clover (*Trifolium pratense* L.): Compatibility. J. Genetics. 21:341-362.

lletin 703 June 1977

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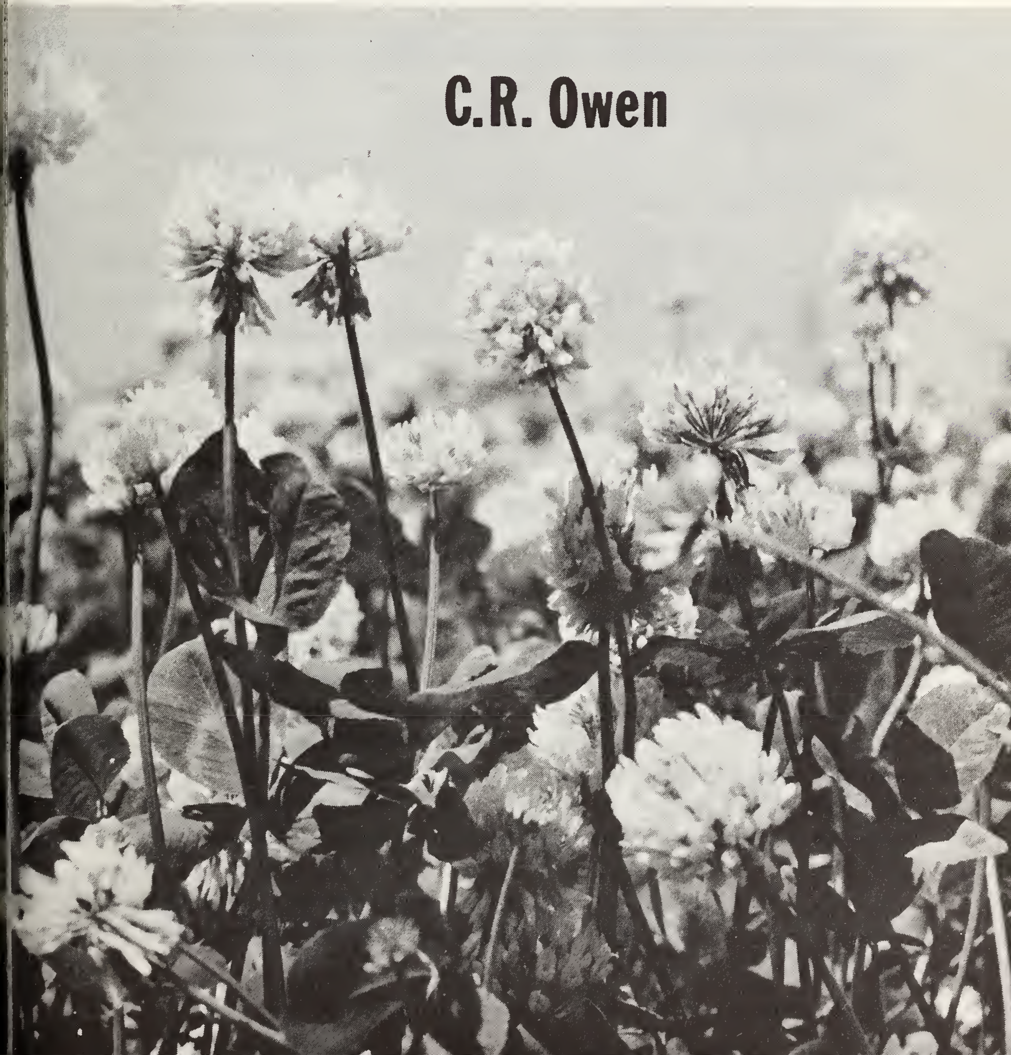
White Clover in Louisiana

C.R. Owen



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White Clover Improvement in Louisiana

C. R. OWEN[1]

Introduction

White clover *(Trifolium repens* L.) has contributed much to the development of grassland agriculture in Louisiana and the southern states. Although apparently little is known of its earliest use, reference is made to white clover during the 19th century (*1*)[2]. In an early Louisiana Agricultural Experiment Station Bulletin *(1)* there is this brief statement: "*Trifolium repens* (white clover) grows wild and luxuriantly all over the south and middle of Louisiana and affords our earliest spring pastures." Prior to comparatively recent times this crop has not been seeded by farmers but it has spread over much of south and central Louisiana by livestock, flood waters, and other natural means.

White clover is thought to have originated in the eastern Mediterranean countries or in Asia Minor. From there it spread throughout western Europe and eventually to other continents (*13*). In the Western Hemisphere, white clover is found growing from Alaska to southern South America. It is found on every continent and most of the major islands, including Greenland (*13*). It is thought to have been brought to the Western Hemisphere as seed in hay fed to livestock while they were on ships (*17*). The seed, being very small and incased in small pods attached in seed heads, were easily scattered by wind, flood waters, birds, and other natural means (*17*). Such widespread distribution of a species would be expected to give rise to many types of white clover, as is the case with corn and other cultivated crops. It is true that white clover is highly variable, and three types are recognized: (*1*) the large type known as Ladino; *(2)* the intermediate type represented by the regional variety Louisiana white clover and that acclimated in New Zealand, and *(3)* the low-growing type of which New York or New England wild white clover is an example. These types result from natural selection within certain regions of the temperate zones. The principal differences among them are in size and general performance. Ladino responds to day length in blooming, whereas the other types are less sensitive to the period of light for normal blooming and seed formation.

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[2] Italic numbers in parentheses refer to Literature Cited, Page 27.

Considerable variation is present within all three types, and there is considerable overlapping in variability, at least between Ladino and the intermediate and between the intermediate and the small New England type.

A program of clover improvement was begun by the Louisiana Agricultural Experiment Station in 1945 for the purpose of producing varieties, strains, or types better suited for use in pastures. It was thought that development of varieties that would produce forage later into the summer would be a worthwhile objective. Improved varieties with the naturally reseeding characteristic should add substantially to the yield if an improved variety is used in pastures which are judiciously managed.

White clover improvement in Louisiana was not restricted to breeding but also included seed production, preparation of seed for marketing, and methods for storing. The protection of white clover from the various insect pests was also part of the program.

Review of Literature

White clover *(Trifolium repens* L.) is considered to have originated in the eastern Mediterranean area or in Asia Minor, according to Gibson and Hollowell *(17)*. They reported that it apparently spread rapidly throughout western Europe. Regarding its spread to the North American Continent, Carrier and Bart *(11)* concluded that evidence pointed to the fact that it was introduced early in the colonization period. They quote an early writer who stated that white clover accompanied the settlements of the white European so closely that it was known by the Indians as ''white man's foot grass.'' Erath *(13)* reported the existence of stands of white clover on every continent and major island. In the tropics it is found at the higher elevations.

Attwood and Hill *(2)* reported on their investigation of meiosis in the microsporophytes of white clover and concluded that it probably was an amphidiploid rather than an autotetraploid and should show disomic inheritance. Attwood *(3)* reported on the genetics of cross-incompatibility among self-incompatible plants. In this report he said seed yield per head under bag is considered an excellent measure of compatibility. The two classes, compatibility and incompatibility, are very distinct. He stated further that the results from experiments with incompatible plants are best explained by the diploid personate type of multiple oppositional allelomorphs, where parents differ in both factors. Attwood *(4)* concluded from experiments with the oppositional alleles that cross-incompatibility between unrelated plants of white clover should be expected very rarely. Further studies by Attwood *(5)* revealed the presence of a factor for self-compatibility to be conditioned by a single gene for self fertility. It was reported to be a member of the multiple allelic series and dominant to the factors for self-incompatibility. Attwood and Sullivan *(7)*found in their studies with a cyanogenetic glucoside that its inheritance was conditioned by two complimentary dominant factors. White clover is recognized as a highly polymorphic species *(8)*. It is largely self sterile, but carries a factor for self fertility, S_f, as well as factors for pseudo-self-fertility. The sterility factors number in excess of 35. Most plants occurring in nature should be cross-compatible.

Gibson *(14)* reported on results from experiments with day length or light period and blooming rates of white clover. The nonflowering clover under normal day length persisted longer than the same clover under the extended light period or the profusely flowering clover under the normal daylight period. The profusely flowering clover under extended light period persisted longer than the nonflowering clover under the normal daylight period. It was found in Louisiana *(23)* that Ladino white clover, the nonblooming type at the latitude of Baton Rouge, bloomed profusely when the light period was extended to 14 hours by the use of fluorescent lights. The persistency was not tested, but it was noted that the acclimated clover did not bloom so profusely at this extended light period. Gibson *et al. (14)* proposed the selection of nonviney types of clones over the viney types for persistence of the synthetic varieties formed from them. Gibson *(14)* proposed a method for evaluating white clover strains by transplanting seedlings into checks at intervals of 6 inches. The results from such plantings compared favorably with solid-seeded plots. This method provides a means of evaluating seed from hand crossing in the greenhouse.

The importance of midsummer diseases was reported by Halpin *et al. (20)*. They stated that southern blight appeared to be closely associated with summer dieback. The plant material was destroyed by the fungi that initiate summer dieback. This dead material served as a substratum for the causal organism of southern blight. They further stated that selecting for resistance to the fungi that incite summer dieback should at least partially control southern blight.

Tisdal and Crandall *(28)* were among the first to report on the use of the polycross progeny performance as an index of combining ability of clones. Clones selected for high combining ability produced synthetic varieties superior to parent varieties in forage yield and definitely better than clones showing low combining ability in polycross progeny.

Interspecific hybrids were made by Gibson and Bienhart *(18)* between *Trifolium repens* (white clover) and a closely related species, *T. occidentale*. *T. occidentale* is a diploid with 16 pairs of chromosomes. *T. repens* has 32 chromosomes and is classed as amplidiploid *(2)*. Success was reported from crossing colchicine-induced tetraploids of *T. occidentale*. Further studies with species hybrids were reported by Gibson *et al. (19)*. These crosses involved another species, *Trifolium uniflorum* with 32 chromosomes, and a colchicine-induced tetraploid of *T. occidentale*. They were successful in combining the three species. They reported the trihybrid as moderately fertile. It was thought by them that these species had certain characteristics that would be desirable to add to white clover. *Trifolium* *uniflorum* has a woody tap root, and *T. occidentale* has resistance to certain viruses.

Among the earlier workers with nitrogen fixation by legumes were Lyon and Bizzell *(22)*. They grew legumes with oats and compared the forage with oats alone. It was found that oat yields were higher when grown with legumes than when oats were grown alone. They also reported an increase in the protein content of the oat forage. Gibson and Hollowell *(17)* reported the nitrogen fixed by white clover to be from 50 to 200 pounds per acre. Harlan *(21)* quoted from Sears in New Zealand, stating that a good sward of New Zealand white clover will fix nitrogen from the air equivalent in available N to 1 ton of ammonium sulfate (21 percent N) to the acre. Smith and Gibson *(27)* discussed the influence of temperature on growth and nodulation of white clover infected with bean yellow mosaic virus. Rhizobia inoculation increased clover yields at temperatures from 50° F to 86° F. They said virus infection decreased the beneficial effects of rhizobia at 62° F and above.

Barrett and Gibson *(9)* reported on the identification and prevalence of white clover viruses in pastures in the southeast. They stated that of 636 white clover plants collected from 19 pastures in 13 southeastern states, 237 were infected with one to three viruses.

Marble *et al.* *(23)* discussed seed production of Ladino white clover in California. They said the honeybee was the most effective pollinator of white clover and that most growers in that area use one ‘‘strong’’ hive per acre, although a few provide three or four such hives per acre. They added that, ‘‘results of recent tests strongly indicate that one to one and one-half strong hives per acre are sufficient for complete pollination.’’ The behavior of honeybees in gathering nectar and pollen was studied by Singh *(26)*. Individual bees were marked with quick-drying paint. The results reported indicated that individual honeybees restrict their activities to comparatively small areas. On alsike clover, he stated, ‘‘a single bee visited an area of 8 feet by 9 feet during a day and confined its total activities to an area of 41 feet by 31 feet.’’

The problems of storing seed of small-seeded legumes have been investigated by Clark and Bass *(12)*. They reported on the effects of storage conditions, packaging materials, and moisture content on the longevity of crimson clover seed. The seed were dried to 5.0 and 6.9 percent moisture content, packaged in containers constructed of various heat sealable materials, and stored up to 11 years at a wide range in temperature and humidity. Materials containing foil afforded the best protection. Under favorable storage conditions, moisture barriers had little effect on the maintenance of germination.

Materials and Methods

Breeding Methods

The first phase of the work with breeding white clover was described previously *(24)*. However, since that publication is out of print and the supply is about exhausted, a brief discussion of the initial phase of the work will be given.

A survey was made of pastures and white clover seed fields in August, 1945, in the Atchafalaya and Red River floodplains. The survey began near the mouth of the Atchafalaya river and extended to Alexandria. Seed heads were taken from wherever they were available. Not many fields or pastures visited had white clover growing during that season, but several hundred seed heads were collected. Those from each field were kept separate and each seed head was put into a small coin envelope.

The seed were separated from each head and counts were made of the number of seed per head. Seed from those heads with the larger number of seed were used for planting. The seedlings were started in greenhouse flats in January and transferred to 6-ounce paper cups when permanent root systems had formed. The seedlings were left in the greenhouse until the danger of a hard freeze had passed; they were set in the field into spaced rows 42 inches apart in drills of the same width in early April.

The nursery was established with seed from 64 seed heads. It was arranged in an 8 x 8 simple lattice experimental design with four replications. The seedlings were set in two-row plots of six hills per row. With the borders and rows planted outside the experimental area, there were more than 4,000 plants under observation in the first planting.

The nursery was cultivated and weeded until the seedlings were established. The nursery was kept free of tall-growing weeds by topping the area with a sickle bar mower.

The following October the percent survival was recorded and surviving plants were measured to determine the extent of spread and the degree of cover the plants had maintained. Finally, 25 clones were selected from the nursery to be transferred to a polycross nursery.

The polycross nursery was established in an isolated area. The plot size was 14 feet x 14 feet with alleys between. The experimental design was a 5 x 5 lattice square with three replications. The clones were transplatnted in the center of the plots in an area 3½ feet x 3½ feet. They were allowed to spread toward the periphera of the large plots.

The clones were evaluated by determining the area covered during the growing season, the maintenance of forage over the area spread, forage yields, and seed yields. These observations were made during two seasons. Following these experiments, the seed of the more outstanding clones were planted in replicated forage and seed yield trials for estimation of their combining ability.

From these experiments, eight clonal lines were isolated. Five of these were combined to form the synthetic variety. This was done by transplanting clone propagules into spaced rows in clone-to-row order and arranging the rows at random with adequate replications to insure random pollination between all clonal lines. When the seed matured they were harvested en masse and thoroughly mixed in the process of cleaning.

After completion of the experiments with the original clones and testing of the synthetic variety, a second cycle clone nursery was established with seedlings from polycross seed of the more outstanding clones. The plan for this experiment was similar to that of the first. From this test some promising clones were isolated, but none was found to be sufficiently superior to the original clones to justify their replacement.

Later in the program, a third experiment was carried out with a collection of clones from areas north of Alexandria. Clonal propagules were taken from pastures and along highway rights-of-way. About 50 clone sections were collected from each of 25 locations; they were taken during late fall, brought to Baton Rouge, and planted in a nursery. They were allowed to spread in competition with the winter, spring, and summer grasses. Tall weeds were kept down by mowing periodically with the mower set above the clover.

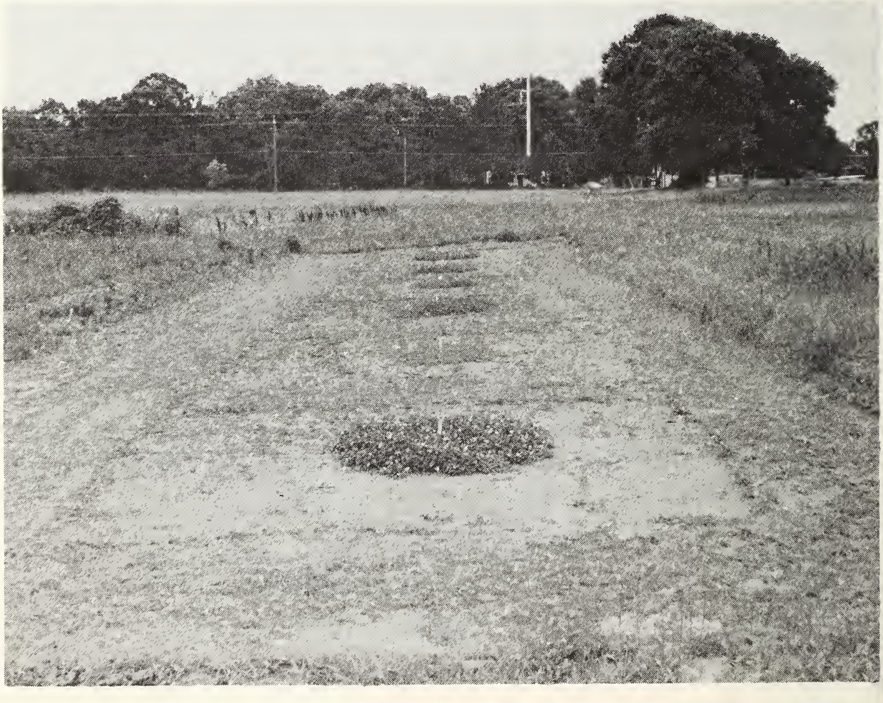

Figure 1. — Clone nursery for increasing clonal lines for the formation of the synthetic variety Louisiana S-1.

Further Experiments With Polycross Progenies

In 1960 an experiment was begun to compare forage and seed production of polycross progeny components with that of the synthetic variety from foundation seed. The experiment was planted on Olivier silt loam soil in late fall. The land was prepared, limed, and fertilized in accordance with that of other such experiments with white clover. The seed from the clones were produced in a polycross nursery in which only the six clonal components of the variety were included. The plot size was 7 feet square and there were four replications arranged in a randomized completed block design.

In 1961, forage harvests were made when the seed were mature. The plots were split and one-half of each plot area was harvested when the early flush of blooms were mature, or about May 15. The second half was harvested one month later. Forage at each harvest was mowed from the plot, bagged, weighed, and dried. The dry weights were taken and the seed threshed from each bag. Seed were separated from the forage and weighed. The plots were mowed later during the summer and fall to remove forage and weeds. In the spring of 1962, forage was harvested from the plots in March, and an application of 0-14-14 fertilizer was made at the rate of 600 pounds per acre. The plots were split as in the previous year, and one-half of each plot was harvested when the early flush of blooms had matured seed, or about May 15, and the second half was harvested one month later. The harvesting routine of the previous year was followed. Seed head size and fertility of florets were studied for each clonal line.

Seed head samples were taken from the experiment comparing forage and seed yields. Ten mature seed heads were taken at random from each of the 36 plots. Each head was placed into a separate small coin envelope, and the envelopes from each plot were put into separate paper bags. In the laboratory, the number of florets from each seed head was determined, and the florets containing seed were separated and counted. These samples were taken just prior to each forage harvest. The average number of florets per seed head and the percent of fertile florets were calculated.

Variety Forage Yield Trials

Forage yield trials with varieties were conduced during most years of the white clover improvement program. The experimental designs were such that statistical treatment of the data was applicable. All variety tests were planted between October 15 and November 15. Rate of seeding was 5 pounds per acre, and the seed were inoculated before planting. The land was prepared by plowing, disking, harrowing, and rolling with a cultipacker. During the process of land preparation, lime and fertilizer were applied as specified by soil tests. The clover forage was harvested in April, May, and June. At harvest the forage was dried and weighed, and the yields reported as pounds of hay per acre (15 percent moisture).

These experiments were conducted to evaluate new strains produced in the breeding program. Standard varieties were usually used as checks. The varieties included in the yield trials were: Regal, a synthetic Ladino-type variety produced by the Alabama Agricultural Experiment Station; Tillman, a synthetic Ladino-type variety produced cooperatively by the Agricultural Research Service, U. S. Department of Agriculture, and the South Carolina Agricultural Experiment Station; Common Ladino, produced by the northwestern clover seed producing area; Louisiana S-1, an intermediate type produced by the Louisiana Agricultural Experiment Station, Baton Rouge; and Nolin's Improved Louisiana White Clover, an intermediate type produced by W. T. Nolin, Hamburg, Louisiana. Forage yield data from these varieties were obtained from 1968 through 1972.

Comparison of Forage Production and Flowering from Seed of Louisiana S-1 Produced in Oregon and in Louisiana

In 1971, samples of seed were procured from representatives of the Oregon State Seed Improvement Association. Samples were received from different lots of registered and certified seed. These samples of seed were representative of seed produced in Oregon for one, two, and three years. This seed was planted in replicated yield trials arranged so that both forage and seed yields were compared. Each test included an entry of foundation seed produced in Louisiana and one of Tillman Ladino. Four samples of seed were procured from Oregon in 1972, and they were planted in similar yield trials for the 1973 growing season. They represented seed grown in Oregon for one, two, three, and four years and were similarly planted for comparison with seed of this variety produced in Louisiana.

The experimental design was a randomized complete block with four replications, with a plot size of 7 feet square. The forage was harvested with a modified rotary mower to which a screen forage catcher was attached. The mower was set to cut the forage 1½ inches above the ground. Blossom counts were made on each plot before harvesting. A 1-foot square quadrant was tossed onto each plot at random and the number of blossoms inside it counted. Three such counts were made on each plot.

Effects of Seed Storage on Viability

In October, 1961, seed of Louisiana S-1 was obtained from a seed grower near Rayne, Louisiana. It was taken from seed lots produced in the 1961 seed harvest. The moisture content had apparently reached equilibrium with the atmosphere.

One-pound samples were taken from this seed and placed in bags made of the following materials: (1) Cotton cloth of medium weight muslin; (2) polyethylene plastic 2 mil., .002 inch thick; (3) polyethylene plastic 6 mil., .006 inch thick, and (4) polyethylene pastic 10 mil., .01 inch thick.

The cloth bags were tied with twine, and the plastic bags were heat sealed. The seed consisting of four bags from each type were separated into four lots. One lot was stored in a metal seed house. The second lot was stored in the forage crop breeding laboratory. Lot 3 was stored in an air-conditioned seed storage room, and Lot 4 was stored in the refrigerator compartment of a seed germinator.

Each seed container was sampled 1 year after storage and for each year afterward for 4 years. The seed was germinated by the Louisiana State Seed Testing Laboratory.

Maintaining Foundation Breeding Stock

Clonal lines were maintained in clonal plots in the field and in the greenhouse. The maintenance of clonal lines followed the standard clover breeding routine. Clonal propagules were transplanted into the center of a plot 14 feet x 14 feet. The clonal lines spread toward the outer boundaries of the plot. For transplanting clones, propagules were taken from the outer edge of the plots. The plots were topped with a rotary mower and the clippings were caught in a wire cage and discarded. Propagules were kept in a nursery for two seasons and then moved to prepared plots.

The synthetic variety was formed by transplanting propagules of each clone into a clone-to-row nursery. About 1 acre was used for the intercrossing block. The clonal lines were transplanted into sets of six rows. The

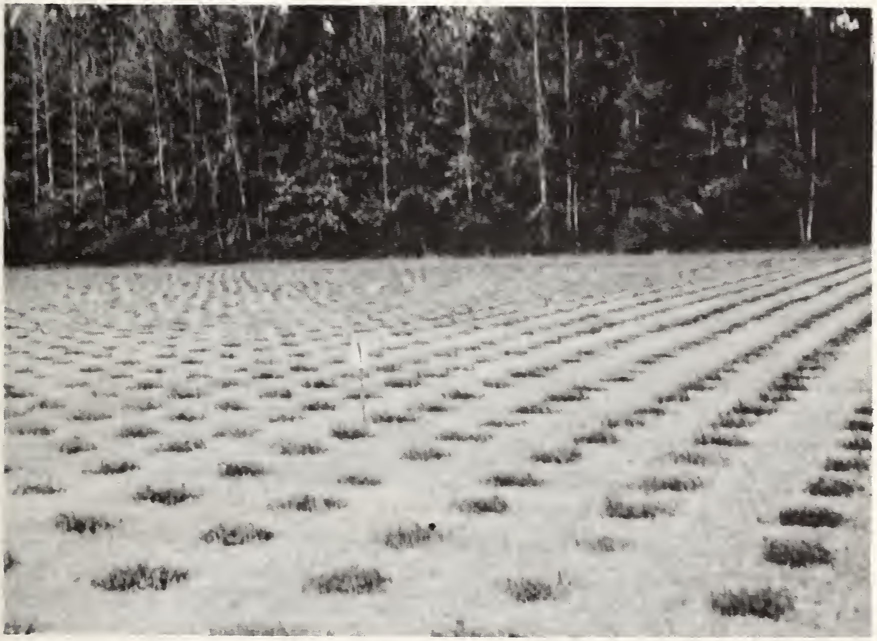

Figure 2. — Clone crossing block for the formation of the synthetic variety.

clonal lines were each assigned a number, the lines were arranged at random, and the sets of rows were replicated from 10 to as many as 20 or more times, depending upon the size and shape of the nursery plot. Breeder seed were harvested en masse from the nursery. The breeder seed were planted at the rate of 1 or 2 pounds per acre in drills 21 inches apart. The size of the blocks for foundation seed was 6 to 10 acres.

Results

The Synthetic Variety

The results from these investigations gave rise to the synthetic variety of white clover designated as Louisiana S-1. A synthetic variety, according to Tisdal and Crandall (*28*), "is a variety that is developed by crossing, compositing or planting together two or more strains or clones, the bulk seed being harvested and replanted in successive generations. By natural intercrossing the strains may be synthesized into a new variety." A synthetic variety can be increased through successive seed generatons as long as the desired characteristics of the variety are retained. In alfalfa, they reported that clones selected for high combining ability by the polycross method produced a synthetic variety having a significantly higher forage yield than standard varieties or low combining clones chosen by the same technique. The clones selected for use in the synthetic variety were chosen for persistence, vegetative vigor, and combining ability.

The forage yields from polycross progenies, common Louisiana white clover, common Ladino, and the synthetic variety are shown in Table 1. It may be noted from the harvest in January that all of the entries lived through the summer after the first year of growth. The differences in forage yield between the polycross progenies and the synthetic varieties were significant, but these differences were less than the differences among the polycross progenies. It may be noted, however, that common Louisiana white clover and Ladino approached the yields of the polycrosses and the synthetic combination more closely during March and May. For June, Ladino was the most productive and Louisiana common was the lowest. For the total yield, the differences between the entries were also significant, but this was largely due to lower forage yields of Louisiana common and Ladino. The forage yields from breeder seed of the synthetic variety were less than that from foundation seed. This has been true throughout the program. Forage production from a synthetic variety may be slightly less than the average yields of the polycross components.

The yield of the synthetic variety when grown in tests with Louisiana common and Ladino is shown in Table 2. The Ladino entry of this test was from seed of common Ladino and was supplied along with seed of Louisiana common white clover by the clover section of the Division of

Table 1. — Forage yield distribution for polycrosses, synthetic varieties, and certain white clover varieties the second year after seeding

	Forage yields, pounds dry matter per acre				
Entry	Jan. 16	March 6	May 8	June 9	Total
S-1 breeder seed	1,111	2,360	3,763	944	8,178
S-1 foundation seed	1,029	2,236	4,099	1,265	8,629
76 Polycross	1,204	2,533	4,205	877	8,819
715 Polycross	1,055	2,600	4,495	1,055	9,205
721 Polycross	1,319	2,569	4,193	899	8,980
723 Polycross	1,212	2,162	4,624	1,399	9,397
726 Polycross	1,325	2,504	4,219	1,399	9,447
Louisiana white	275	2,020	3,752	355	6,602
Ladino	604	1,725	3,555	2,520	8,404
Mean	1,015	2,301	4,100	1,190	8,629
LSD (5%)	118	302	651	426	1,053

Forage Crops and Disease, U. S. Department of Agriculture. These results were obtained early in the program and are presented to show the relationship between the yield of Louisiana S-1, Ladino, and Louisiana common white clover. After the synthetic variety was released for seed production and became spread over the state, it was no longer possible to procure seed of Louisiana common for comparative testing. Consequently, recent comparisons of Louisiana S-1 with common white clover were not available. Fields of common white clover overseeded with Louisiana S-1 would, of course, be influenced by the improved variety.

Total forage yields for 1951, 1952, and 1953, and the average of the total yields for the 3 years, are shown in Table 2. These data do not give the seasonal distribution, but as shown in Table 1 the larger difference between Louisiana S-1 and Louisiana common occurred in June and later in the summer. Ladino produced less during March, April, and May. Forage yields of Ladino exceeded those of Louisiana S-1 in harvests made later than May. Only the total annual yield and the average of the total yields are shown in Table 2. In average total yield, Louisiana S-1 exceeded Ladino by 10 percent and Louisiana common, the variety it was developed from, by 27 percent.

Table 2.—Forage production with cultivars and strains of white clover

	Forage yields, pounds dry matter per acre				
Entry	1950	1951	1952	Avg.	% of check
Louisiana S-1 white clover	8,333	3,427	7,809	6,523	127
Ladino	6,749	3,643	7,577	5,990	117
Louisiana white clover	6,696	3,043	5,632	5,124	100
LSD (5%)	207	294	249		

A Further Experiment with Polycross Progenies

Results from this experiment are shown in Table 3. Yields of both forage and seed were lower than normal for white clover in this area. This experiment was conducted about 10 years after Louisiana S-1 was released. The comparison shows that the clonal lines that had been carried in the nurseries to maintain their hereditary characteristics did this insofar as could be detected in such yield trials. Unfortunately, neither Louisiana common nor Ladino was included, and a comparison of these could not be made. However, it may be observed from data in Table 3 that differences between the entries for forage production were not significant except for yields from the harvest made in June, 1961. Seed yields of polycross progenies were compared with those of the synthetic variety. Results showed that seed yields were erratic and differed from season to season. In 1961, yields of seed from forage harvested in May were less than from that harvested in June. For the 1962 harvests, yields were much larger in May than in June. Forage yields were less in 1962 than in 1961 for both harvests. The mean yield of all entries for May, 1961, was 4,012 pounds per acre and for 1962 it was 1,993 pounds. In 1961, the first year after seeding, the yield of seed from the May harvest was low. Seedling clover does not bloom as early in the spring as does growth from stolons that lived over from the previous season. Obviously the yields of seed in 1962 came from second-year stolons. Blooming began earlier in the spring, and consequently the yield of seed from forage harvested in May was larger than from forage harvested in June. The low yield in June was most likely due to weather conditions. There were significant differences between the entries at each harvest except that of June, 1962, when yields were so low as to not be representative of normal growth. Such low yields of seed from plots that had not been harvested previously during the season were due to unfavorable weather conditions that occurred after the harvest in May.

Comparison of Seed Head Size and Fertility of Florets

The differences between entries for either the number of florets or percent of fertile florets were not significant, except for the percent of fertile florets from those sampled in June, 1962. The average number of florets on seed heads from these plots was 66.9, and the average percentage of fertile florets was 60.0 (Table 4). The samples taken from the plots in June, 1962, contained the smallest seed heads and were lowest in percent of fertile florets. Of the factors contributing to seed yield, these, together with the density of seed heads, are most important. The density of seed heads, or the number within a given area, was not determined. Undoubtedly it was low at this last forage harvest. Seed heads of white clover are fragile after the seed are mature, and they do not withstand frequent showers or unusually hot, dry weather well.

Table 3.—Forage and seed yields of the polycross progenies of the clone components and the synthetic variety, first and second year after seeding

Entry	Forage yields, pounds dry matter per acre				Yield of seed, pounds per acre			
	Harvested in May		Harvested in June		Harvested in May		Harvested in June	
	1961	1962	1961	1962	1961	1962	1961	1962
La. S-1 foundation seed	4,458	1,969	3,374	1,416	42	70	77	4
Polycross 76	3,694	2,253	2,468	1,363	64	63	78	3
Polycross 711	4,191	1,942	2,877	1,328	32	56	70	5
Polycross 715	3,605	2,098	2,593	1,323	79	66	90	2
Polycross 721	4,183	1,947	2,895	1,194	58	47	89	4
Polycross 723	4,209	2,022	2,949	1,314	44	49	80	3
Polycross 726	3,747	1,720	2,344	1,207	42	37	52	5
Mean	4,012	1,993	2,786	1,306	51.6	35.4	76.6	3.7
LSD (5%)	—	—	57.0	—	6.0	6.0	21.0	—

Table 4.—Number of florets per seed head and fertility of florets of polycross components and the synthetic variety, 1961 and 1962

	Number florets per seed head				Percent fertile florets			
	Sampled in May		Sampled in June		Sampled in May		Sampled in June	
Entry	1961	1962	1961	1962	1961	1962	1961	1962
La. S-1 foundation seed	73.2	78.0	78.3	57.5	53.0	71.1	65.2	74.5
Polycross 76	70.8	78.9	64.9	55.3	65.7	56.6	54.9	48.5
Polycross 711	67.9	69.7	67.9	53.5	60.8	70.1	61.1	42.1
Polycross 715	61.4	72.6	74.4	58.5	70.1	48.0	77.3	50.8
Polycross 721	66.4	64.6	69.0	54.6	71.2	60.1	64.6	38.5
Polycross 723	64.5	76.4	79.0	64.8	75.7	58.4	64.9	41.3
Polycross 726	66.2	66.2	67.6	54.0	66.3	63.9	54.8	45.9
Mean	67.2	72.1	72.3	56.1	66.4	61.2	63.2	49.1
LSD (5%)	—	—	—	—	—	—	—	10.4

Forage Yield Trials with Varieties

Varieties of white clover available for planting in Louisiana and the Southeastern Region are not numerous. Forage yield trials with varieties included only five entries. These are not all planted extensively in Louisiana, but were included to provide a comparison of forage yields among the varieties available. Total forage yields of the different varieties from 1968 through 1972 were not significantly different (Table 5). However, one important difference among varieties for Louisiana and other areas of similar latitude is the blooming rate. None of the Ladino-type varieties bloom sufficiently in Louisiana to produce seed for reseeding. With the hazards white clover is subjected to, reseeding is an important characteristic if the crop is desired from year to year. Droughts, insects, and diseases can take a heavy toll of the stands. If not lost entirely, they may be thinned until reestablishment is necessary unless enough seed is produced for reseeding. The reseeding varieties included in Table 5 are Louisiana S-1 and Nolin's Improved Louisiana White Clover.

Seasonal Forage Yields

Differences between varieties in distribution of forage may be important in selecting a variety to use. Average forage yields from four seasons of harvests made in April, May, and June are shown in Table 6. Harvests were made in August in certain years, but they are not included. Consequently, forage yields are less than those reported in Table 5, and data in Table 6 are from the average for 4 years instead of 5 years as in Table 5.

Table 5.—Forage yields of white clover varieties grown on Olivier silt loam at Baton Rouge, 1968-72

Variety	1968	1969	1970	1971	1972	Average
	- - - - - - - - - - - - - -	Pounds of hay per acre	- - - - - - - - - - - - - -			
Regal	6,636	6,918	5,846	6,995	8,474	6,974
Tillman	5,700	7,656	6,523	6,114	8,835	6,964
Louisiana S-1	5,913	6,967	7,514	6,262	7,775	6,886
Nolin's Improved	5,803	6,908	7,616	5,828	6,890	6,609
Ladino Common	5,494	7,401	6,280	6,251	6,939	6,473
Average	5,908	7,149	6,903	6,188	7,476	6,725
LSD (5%)	121	708	—	—	—	—

Results given in Table 6 show that 53 percent of the forage yield for Nolin's Improved and 50 percent for Louisiana S-1 were taken at the first

Table 6. — Forage distribution of white clover varieties grown on Oliver silt loam at Baton Rouge, average for 1968-71

Variety	April	May	June	Total
	- - - - - - - - - - -	Pounds hay per acre	- - - - - - - - - - -	
Louisiana S-1	3,307	1,990	1,293	6,590
Tillman	2,497	2,309	1,760	6,566
Regal	2,680	2,318	1,470	6,468
Nolin's Improved	3,416	1,918	1,099	6,433
Ladino Common	2,760	2,057	1,318	6,135
Average	2,932	2,118	1,388	6,438

harvest, made in early April. With varieties of the large type, Tillman gave 36 percent of its growth before the April harvest, the yield taken in May was only slightly less, and the June harvest represented 25 percent of the total yield.

Reseeding varieties, such as Nolin's Improved and Louisiana S-1, produced more forage early in the season. Vegetative growth was retarded as the heavy blossoming season approached, while varieties that produced no flowers, and hence no seed, continued vegetative growth when weather conditions were favorable. Selecting a variety for planting from those included in Table 5 and 6 may depend upon the season of the year that the bulk of the forage is desired. The reseeding characteristic also is important in Gulf Coast states because of the probable loss of stands during summer and fall months. A blend of seed from each of the two types might be used if maximum use of clover for pasture is desired.

Comparison of Forage and Seed Yields from Seed Produced in Oregon and in Louisiana

Forage and seed yields from the first planting are shown in Table 7. Four forage harvests were made, in late March and in May, June, and August. Seed were harvested in June from a test planted principally for seed production. A forage harvest was made in late March from this test, but since it did not differ from the test for forage the results from it are not reported.

Forage yields averaged 3,132 pounds of hay per acre for the early harvest, 1,634 pounds for May, 2,095 pounds for June, and 1,721 pounds for August. No harvest was made in July because the rate of growth in hot weather from a freshly mowed plot is not sufficient to compete with weed growth. The average total yield for the season was 8,592 pounds of hay per acre. At no harvest was there a yield difference in forage that was significant at the .05 level of probability. There were yield differences, but mostly favoring the Oregon seed. Such differences are thought to be due to better

Table 7.—Forage and seed yields from Louisiana S-1 seed produced in Oregon and in Louisiana, 1972

Variety	Date harvested				Total	Yield of seed lbs./A.
	March 27	May 3	June 6	Aug. 23		
	Pounds of hay per acre					
Oregon Certified 1WC83	3,246	1,832	2,121	1,882	9,081	141
Oregon Registered OWC942	3,286	1,703	2,220	1,723	8,932	129
Oregon Registered L75-013	3,216	1,732	2,131	1,585	8,664	154
Oregon Certified OWC101	3,107	1,623	2,011	1,762	8,503	139
Oregon Certified W91WC4	3,186	1,573	1,972	1,713	8,444	171
Louisiana S-1 foundation	3,087	1,523	2,031	1,723	8,364	167
Ladino	2,798	1,513	2,181	1,663	8,155	13
Average	3,132	1,643	2,095	1,721	8,592	
CV (%)	8.0	13.0	19.0	18.0	—	8.6
LSD (5%)	—	—	—	—	—	12.8

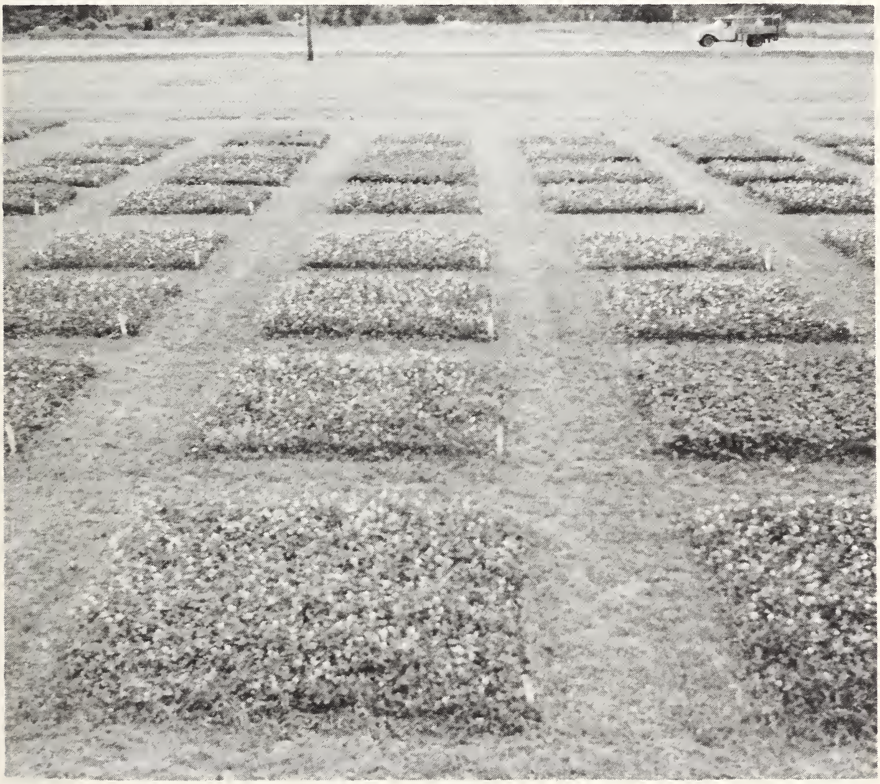

Figure 3. — Experimental plots with Louisiana S-1 white clover seed produced in Oregon and in Louisiana; note the uniformity of forage from plot to plot.

developed seed in the northwest. There were differences between certain entries for yields of seed. Locally grown seed produced 167 pounds of seed per acre while an entry from Oregon produced 171 pounds. Ladino gave the low yield of 13 pounds. These experiments were conducted for only 1 year on the same plots. The second planting was made on different plots in the fall of 1972 with additional samples from Oregon.

Results from forage and seed yield experiments planted in the fall of 1972 and harvested during the spring of 1973 are shown in Table 8. These experiments were planted in a block adjacent to those experiments conducted in 1972. Forage harvests were made in April, May, and June. Forage from the seed plots was harvested July 2. Forage production from each cutting did not differ excessively from that in corresponding months in 1972. Total yield was less because the test was abandoned after the June harvest. Represented in these experiments are seed samples from lots produced in Oregon for 2, 3, and 4 years. It may also be noted that none of the entries differed significantly from the plots planted with locally produced seed. There was a significant difference between Ladino and the S-1 entries for the June harvest. Ladino exceeded these entries only for the June harvest. The differences between entries from Louisiana S-1 at this harvest were not significant.

Seed production was low for the 1973 season. The low yield may have been caused by the delayed harvest. It was made July 2, which is late for harvesting seed of this clover at this location. There was a highly significant difference in the yields of seed. Certain entries from Oregon produced

Table 8.—Forage and seed yields from Louisiana S-1 white clover from seed produced in Oregon and in Louisiana, compared in Louisiana, 1973

Variety	Date harvested			Total	Yield of seed, lbs./A.
	April 4	May 12	June		
	- - - - - Pounds hay per acre - - - - -				
Ladino	2,515	1,585	2,024	6,124	3.8
Louisiana S-1 local seed	2,545	1,697	1,400	5,642	23.3
La. S-1 Oregon, 2nd year registered	2,699	1,677	1,308	5,683	25.6
La. S-1 Oregon, 2nd year certified	2,628	1,727	1,236	5,591	31.5
La. S-1 Oregon, 3rd year certified	2,678	1,616	1,349	5,643	27.6
La. S-1 Oregon, 4th year certified	2,699	1,616	1,441	5,756	17.2
Average	2,627	1,653	1,460	5,739	21.5
CV (%)	20.0	18.6	10.8	—	18.4
LSD (5%)	—	—	204	—	6.0

higher yields than entries from local seed. The entry from the seed sample planted in Oregon for 4 years produced significantly less than the entry from local seed. This may indicate a tendency toward a change in the blooming rate of this variety, but because of the yield of seed from the other entries the change should not be considered excessive. Seed production from Ladino was 3.8 pounds, compared with the average for all entries of 21.5 pounds per acre.

Blooming Rate

Blooming rate, measured in the number of seed heads per square foot, is shown in Table 9. The blooming rate varies significantly for the counts made during May and June and July, but this difference is not altogether reflected in the yield of seed shown in Table 8. Such discrepancies might be explained by the way the seed heads were counted. No distinction was made between mature and immature seed heads when the count was tabulated. Obviously, the entry with the largest number of immature seed heads at a seed harvest would yield less seed than those with more mature heads.

Seed Production

Seed production with white clover in Louisiana is a specialty farm enterprise requiring certain technical skills, which may be gained principally by experience. It entails considerably more risk than most other crops under cultivation in the state. Most of the seed of S-1 are produced in the northwestern states, but it is possible to produce a fair yield of good quality seed in Louisiana. Before attempting such an enterprise it would be well to consider certain practices that may or may not apply to other crops. Yields of seed in the humid area of the United States vary from 30 to 200 pounds

Table 9. — Blooming rate of Louisiana S-1 white clover from seed produced in Oregon and in Louisiana, 1973

Variety	Date of count April 4	May 10	June 18	July 2
	- - - - - - - - - Number	blooms per	square foot - - - - - - - - -	
Ladino	0	0.25	1.31	1.4
Louisiana S-1 foundation seed	2.8	27.5	58.4	45.9
Oregon, 2nd year registered	4.2	28.0	51.4	41.7
Oregon, 2nd year certified	3.5	24.5	42.7	34.0
Oregon, 3rd year certified	2.5	21.0	43.8	42.3
Oregon, 4th year certified	3.5	25.7	46.4	40.1
Average	2.7	21.1	40.7	34.2
CV (%)	40.0	14.9	11.2	24.0
LSD (5%)	—	4.8	6.9	6.2

per acre *(17)*, but acre yields of over 300 pounds have been produced in Louisiana. Such yields are, of course, the exception, and while they are possible, prospective seed producers would do well to consider the average yields. Sometimes the yields may be less than the average, depending upon weather conditions prior to and during the seed harvesting period.

Producers of seed of an improved variety should begin by planting foundation seed, and from such planting produce registered or certified seed. Standards for the production of registered or certified seed for Louisiana S-1 white clover, as well as other crop seeds, may be obtained by writing the certifying agency of the state. For Louisiana, the certifying agency is the State Department of Agriculture. The standards are set up to safeguard the quality the buyer of certified seed has a right to expect. The quality found in certified seed is the result of the extra precautions taken prior to the time the seed is bagged.

White clover for seed production should be planted on the heavier soil types. The soil should have good water retention capacity, yet be sufficiently well drained to prevent water from remaining on the surface for extended periods. Other factors to be considered in white clover seed production include 1) using adequate quantities of the right kinds of fertilizer and lime, which should be determined from soil tests; 2) preparing the land well to furnish the best type of seedbed; and 3) keeping weeds under control after the clover begins growing. Still other considerations are such things as 1) rate and time of seeding; 2) seed inoculation, particularly on land suitable for producing certified seed as such land should not have produced clover during the previous 3 to 5 years and thus the inoculant would be needed; 3) and adequate supply of pollinating insects; and 4) seed harvesting and cleaning machinery.

Land preparation is more important for a crop that is to occupy the land 3 or more years than for those which occupy the land for only one season. Regardless of the extent to which other practices are fulfilled, white clover planted on a cloddy, loose seedbed is likely to be less productive than it would be needed; 3) an adequate supply of pollinating insects; and 4) seed

Weed control is as essential with a crop such as white clover seed as it is with any other crop. Of course, after the crop is seeded very little cultivation is possible, and growers must resort to mowing and the judicious use of herbicides. Mowing should begin as early as necessary if it is to be used as the method of weed control. Since there has been considerable development in the field, it would be best to consult Cooperative Extension Service or Agricultural Experiment Station representatives regarding use of herbicides in controlling weeds in white clover.

Topping fields of white clover by mowing just before the peak blooming period will likely be necessary to reduce rank growth of forage. Control of dodder *(Cuscuta arvensis)* is not possible by mowing. It is a most objectionable noxious weed and special care should be taken to keep clover fields from becoming contaminated with it. Dodder is more severe during years when white clover seed is late in reaching maturity. When a field becomes severely infested, it is usually best to plow the crop under and follow it with a cultivated row crop. When the infestation is light, dodder may be destroyed by burning or by spot treating with a herbicide. The field should be inspected early for the presence of dodder, which may be destroyed by cutting the small patches of infested clover with a hand scythe and removing them from the field. Curly dock *(Rumex spp.)* is difficult to control in seed fields if it gets a start. It cannot be controlled by mowing or burning but can be controlled by the use of the herbicide 2-4-D sprayed on the field during the autumnal season.

Pollination

As previously mentioned, white clover is mostly self-sterile and must be cross-pollinated by insects to produce seed. Fields of wild white clover or pastures may be adequately pollinated for reseeding by wild honey bees and other insects. Where seed production is intended, it is best not to depend upon natural pollination. Marble *et al. (23)* stated that, ''Most growers of Ladino clover seed in California now use a minimum of one 'strong' honeybee hive per acre; a few use three or four such hives per acre.'' A strong hive has brood in not less than seven combs and bees enough to cover no less than 15 frames in a two-story hive *(23)*. This number of hives may be excessive in Louisiana. Farmers considering seed production with white clover should acquire as many bee hives as is practical for pollination. Without adequate pollinating insects, seed set may be low.

Seed Harvesting

White clover seed may be matured sufficiently for harvesting 4 to 5 weeks after the peak blooming period has passed. The peak of blooming occurs when the decline in vegetative growth rate begins. Seed are mature in a seed head when the supporting stems lose the green color. Harvesting should be done when about 75 percent of the heads in the field are mature. Weather reports should be the determining factor for beginning harvesting when this stage of maturity is reached.

Harvesting is done by cutting the clover with a mowing machine. It is left in the swath until the foliage is dry, after which it is either threshed from the swath by the use of a combine with a windrow pickup attachment or windrowed and threshed from the windrow. With the limited acreage grown on the Louisiana Agricultural Experiment Station farm, a pickup reel has been used satisfactorily. With a narrow-width combine (72 inches or less), the pickup reel has been used for harvesting either from the windrow or from the swath. For a wide-swath combine (10 feet or more), the mower swaths should be windrowed for the reason that the large combine will leave some of the swaths untouched unless the surface of the ground is perfectly level, and very few fields are. Large combines may thresh two windrows per trip.

Combines were not necessarily designed for threshing small seed, but were built for threshing cereal grain and larger seed. Careful adjustment may be necessary for best results when using these machines with clover seed. Every precaution should be taken to make necessary adjustments as soon as is practical after the threshing operation begins.

Cleaning the Seed

Two types of seed-cleaning machines are usually required to clean white clover seed after it has been threshed with the standard combine or thresher. In one type machine, seed are run over screens which remove foreign material, such as large stems and other substances larger than the seed. This machine is also equipped with an air blast that removes dust and certain of the lighter materials. For complete cleaning of the seed, a second machine is essential. This machine is known as the gravity seed separator. It completes the separation of small pieces of straw, light immature seed, and other material lighter than the seed. Improvements are being made constantly in seed-cleaning machinery. Such machines are costly and operating them successfully requires some skills gained by experience. It will probably be more practical for most seed producers to depend upon commercial cleaners for cleaning their seed. Growers of certified seed should consult the certifying agency for a list of commercial plants that meet the requirements for cleaning such seed.

Seed Storage

Experiments conducted with seed storage showed that viability of white clover seed was maintained for a considerable number of years if seed were packaged in moisture retention containers and stored at 35° to 45° Fahrenheit. Seed stored in cloth bags under ordinary storage conditions lost about 20 percent of their viability during storage for 1 year, and during 5 years of storage the loss in viability was 98 percent. Under cold storage conditions, seed stored in cotton cloth bags lost 14 percent of their viability during 5 years of storage. Seed stored in polyethylene plastic bags maintained viability better under all storage conditions than that in cotton cloth bags.

Obviously, cold storage is best for storing seed of any type. Cold storage with moisture retention bags is best. Seed packaged in heavy polyethylene bags lined with heavy cotton cloth kept in cold storage for 7 years had 90 percent germination with no hard seed.

Insect Pests*

Several species of insects attack white clover in Louisiana. Some may reduce both forage and seed yields, while others primarily damage seed and reduce seed yields. Some are general feeders on many species of plants, whereas others are restricted to attacking some species of legumes. A brief description of the most important pests follows.

Clover head weevil: The clover head weevil, *Hypera meles* (F.), is primarily responsible for poor seed yields of white clover in Louisiana. Eggs are deposited in the stems and the larvae are found in the clover heads where they feed on the flowers and developing seed. Their feeding causes small abnormal seed heads and reduces seed production. Adults feed primarily on leaves and apparently cause little damage to the crop. The adult is brown, about three-sixteenths of an inch long, and has three longitudinal whitish stripes along its topline. The full grown larva is legless with a rusty-brown head. Generally it is yellowish with faint brown or bluish longitudinal stripes. The insect overwinters as an adult and deposits its eggs in slits in the petiole or stems during the spring. Only one generation a year occurs in Louisiana.

Spider mites: Spider mites are extremely small mites that often damage white clover by feeding on the underside of the leaves where they suck juices from the plant. Infested leaves have yellow patches that range in size from small specks to large areas. A heavy infestation of spider mites can virtually destroy a clover crop.

Cutworms: The variegated cutworm, *Peridoma saucia* (Hubner), is the most destructive of the cutworms attacking white clover in Louisiana. It is 1½ to 2 inches long when full grown and may be identified by the four to six yellow spots along the back. Cutworms injure plants by cutting them off at or just below the soil surface. They usually feed at night and hide during the day, frequently in a semi-coiled position near the destroyed plant.

Aphids: Two species of aphids, the cowpea aphid and the yellow clover aphid, infest clover in Louisiana. These aphids can be present in large numbers without apparent injury to the plants. They are sap-sucking insects and heavy infestations may cause the plants to wilt and become stunted and discolored. Excretions of honeydew cause the flower parts to stick together in clumps resulting in reduced seed yields.

Alfalfa weevil: Alfalfa is the preferred host of the alfalfa weevil, *Hypera postica* (Gyllenhal). Clover is often attacked in Louisiana. Eggs are deposited in the stems. The larvae cause most of the damage by initially feeding in the stems and subsequently moving to the terminal leaf buds of the plants where they feed on the young buds and later on leaves. Their feeding skeletonizes the leaves, which stunts plant growth and reduces yields of forage and seed. The full grown larva is legless, about three-eighths of an inch long, and green with a brown head and a white stripe along the back. The larvae tend to curl and bring the tip of the head and the abdomen together when held in the hand.

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*Discussion prepared by B. H. Wilson, Professor, Department of Entomology, LSU Agricultural Experiment Station, Baton Rouge.

Clover root curculio: Larvae of the clover root curculio, *Sitona hispidula* (F), feed on tender roots and chew large cavities in the main roots. Clover roots infested by these insects will often die, especially during periods of dry weather. The larvae are small, grayish-white, footless grubs about one-sixteenth of an inch long that can be found in the roots of infested plants. The adults are small grayish or brownish beetles with short, blunt snouts that eat out rounded areas from the leaves and gnaw on stems and leaf buds during the day.

Plant bugs: Plant bugs (*Lygus spp.)* are sap-sucking insects that can greatly reduce seed yields by feeding on flowers and developing seed. Both adult and nymphal lygus severely injure clover, but the nymphs are more serious pests than the adults. Adult lygus are about one-fourth inch long, have four wings that lie flat on the back, and are marked by a distinct ''V'' on the back just in front of the wings. Nymphs have black spots on their backs. Lygus nymphs are usually green or yellowish-green while adults are light green, various shades of brown, or almost black.

Other insect pests: Several other insects may cause damage to white clover in Louisiana. The southern green stink bug, *Nezara viridula* (L), may reduce seed yields by feeding on flowers of developing seed. The corn ear worm, *Heliothis zeae* (Boddie), and the tobacco bud worm, *Heliothis virescens* L, also attack seed heads and are capable of substantially reducing seed yield. The fall army worm, *Spodoptera frugiperda* (P. E. Smith), sometimes attacks the foliage in late summer and early fall and may defoliate a field if not controlled.

Control: Most of the serious pests of white clover can be controlled with insecticides. Recommendations for insect control are constantly being modified and improved. County agricultural agents should be consulted for latest recommendations. Honey bees and other pollinating insects are very susceptible to some insecticides. Insecticide applications should be made in the evenings or other times of the day when these insects are not active in the fields.

Summary

The white clover improvement program conducted by the Louisiana Agricultural Experiment Station has resulted in the isolation of superior clonal lines which, when combined into a synthetic variety, have performed sufficiently well to warrant their use during the past 25 years. Originally the synthetic variety, Louisiana S-1, was composed of five clonal lines; a sixth line was added in the release of the variety.

Since the release of Louisiana S-1, thousands of clones have been screened and dozens of clone combinations have been formed into experimental synthetic varieties. However, none has been tested that was considered sufficiently superior to S-1 to replace it, although a number of excellent clonal lines have been isolated and evaluated.

The breeding stock, consisting of six clonal lines, is maintained by the Louisiana Agricultural Experiment Station for the purpose of supplying seed growers with seed that is constant in genetic purity.

Variety tests over a period of years show that varieties that reseed naturally are probably to be preferred in Louisiana over the nonblooming types adapted to areas farther north.

Literature Cited

1. Anonymous. 1892. Forage crops, grasses, clovers and small grains. Bull. 19. Second series. La. Agr. Expt. Sta. p. 543.
2. Attwood, S. S. and Helen D. Hill. 1940. The regularity of meiosis in microsporocytes of *Trifolium repens*. Amer. J. Bot. 27:730-735.
3. ———. 1940. Genetics of cross-incompatibility among self-compatible plants of *Trifolium repens*. J. Amer. Soc. Agron. 32:955-968.
4. ———. 1941. Oppositional allels causing cross-incompatibility in *Trifolium repens*. Genetics 27:333-338.
5. ———. 1942. Genetics of self-compatibility in *Trifolium repens*. J. Amer. Soc. Agron. 34:353-364.
6. ———. 1943. "Natural-crossing" in white clover by bees. J. Amer. Soc. Agron. 35:862-870.
7. ——— and J. T. Sullivan. 1943. Inheritance of a cyanogenetic glucoside and its hydrolyzing enzyme in *Trifolium repens*. J. Hered. 24:311-320.
8. ———. 1947. Cytogenetics and breeding forage crops. Adv. in Genetics 1:52-55.
9. Barrett, O. W. and P. B. Gibson. 1975. Identification and prevalence of white clover viruses and the resistance of trifolium species to these viruses. Crop Sci. 15:32-37.
10. Bula, R. J., R. G. May, C. S. Garrison, C. M. Rincken and D. R. McAllister. 1964. Growth response of white clover *(Trifolium repens* L.) progenies from five diverse geographic locations. Crop Sci. 4:295-297.
11. Carrier, L. and K. S. Bort. 1916. The history of Kentucky bluegrass and white clover in the United States. J. Amer. Soc. Agron. 8:256-266.
12. Clark, D. C. and L. N. Bass. 1975. Effects of storage conditions, packaging materials and moisture content on longevity of crimson clover seed. Crop Sci. 15:577-580.
13. Erath, A. G. 1924. White clover *(Trifolium repens* L.) A monograph. 150 pp. Duckworth and Co., London.

14. Gibson, P. B. 1957. Effect of flowering on the persistence of white clover. Agron. J. 49:213-215.

15. ———, G. Beinhart, J. F. Halpin and E. A. Hollowell. 1963. Selection and evaluation of white clover clones: I. Basis for selection and a comparison of two methods of propagating for advanced evaluations. Crop Sci. 3:83-86.

16. ———. 1964. A technique requiring few seed for evaluating white clover strains. Crop Sci. 4:344-345.

17. ——— and E. A. Hollowell. 1969. White Clover. Agr. Handbook 214. U.S.D.A., A.R.S. 33 pp.

18. ——— and G. Beinhart. 1969. Hybridization of Trifolium occidentals with two other species of clover. J. Hered. 60:93-96.

19. ———, Chi-Chang Chen, J. T. Gillingham and O. W. Barnett. 1971. Interspecific hybridization of Trifolium uniflorium. Crop Sci. 11:895-899.

20. Halpin, J. E., P. B. Gibson, G. Beinhart and E. A. Hollowell. 1963. Selection and evaluation of white clover: II. The role of midsummer diseases. Crop Sci. 3:87-89.

21. Harlan, Jack R. 1956. Theory and dynamics of grassland agriculture. D. Van Nostrand Company. Princeton, New Jersey. 91-94.

22. Lyon, T. L. and J. A. Bizzell. 1911. A heretofore unnoticed benefit from growing legumes. Cornell Agr. Expt. Sta. Bull. 294. 11 pp.

23. Marble, B. L., L. G. Jones, J. R. Goss, R. B. Jeter, V. E. Burton and D. H. Hall. 1970. Ladino clover seed production in California. Cal. Agr. Expt. Sta. Cir. 554. 33 pp.

24. Owen, C. R. 1953. Louisiana S-1 white clover. La. Agr. Expt. Sta. Bull. 479. 15 pp.

25. Piper, C. V. 1927. Forage crops and their culture. The Macmillan Company, New York. 473-479.

26. Singh, Sardar. 1950. Behavior studies of honeybees in gathering nectar and pollen. Cornell Univ. Agr. Expt. Sta. Memoir 288. 56 pp.

27. Smith, R. H. and P. B. Gibson. 1960. The influence of temperature on growth and nodulation of white clover with bean yellow mosaic virus. Agron. J. 52:5-7.

28. Tisdal, H. M. and Bliss H. Crandall. 1948. The polycross progeny performance as an index of combining ability of alfalfa clones. J. Amer. Soc. Agron. 48:293-306.

September 1977

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Bulletin No. 704

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Acknowledgments

The authors are indebted to Mr. R. H. Brupbacher and the staff of the Louisiana State University Soil Testing Laboratory for analytical work on some of the soil samples involved in this study. Gratitude is also expressed to Mr. E. A. Epps and the staff of the Louisiana Feed and Fertilizer Laboratory for analysis of some of the sweet potato foliar samples.

Effects of Soil Amendment and Fertilizer Applications on Sweet Potato Growth, Production, and Quality

L. G. JONES, R. J. CONSTANTIN, J. M. CANNON, W. J. MARTIN, and T. P. HERNANDEZ[1]

Introduction

Sweet potatoes are grown in Louisiana on several different types of soil. The soils range from the light-textured, moderately acid Coastal Plains group through the medium-textured, moderately acid Mississippi River terrace and Loessial Hill group to the heavier-textured, slightly acid to neutral soils of the Mississippi and Red River alluvial areas. Some of the soils in the first two groups are strongly acid, having a pH of 5.0 or lower, and a portion of the third group are alkaline, with a pH of 7.0 to 7.5 *(7)*[2]. The natural reaction of some of these soils has been altered in certain fields to some extent by the continued use of fertilizers and/or lime to make them more suitable for the production of crops. As a result of these practices, the pH of any one of the soils mentioned above may vary over quite a wide range.

A high percentage of the commercial sweet potato crop in Louisiana is produced on silt loam soil of the Mississippi River terrace or Loessial Hill group. Generally, the reaction of these soils is acid, varying in pH from 4.8 to 5.8 under natural conditions. However, many of these soils have received lime applications to make them more suitable for production of soybeans, as well as other leguminous crops and certain non-legumes, so that the present pH of some of these soils is above 6.0. Still, they are used to some extent by sweet potato growers, even though they are aware of the potential damage to their crop by the soil rot organism *Streptomyces ipomoea*, as pointed out by Person and Martin *(35)*. On the other hand, these soils are purposely avoided by some growers of sweet potatoes who are not willing to risk their crop on a terrace or Loessial Hill soil that has been limed. Rather, these growers prefer to use unlimed soil with a pH not much above 5.0 because of their knowledge of or experience with the soil rot problem. Accordingly, through the continuous use of complete fertilizer and long-term cropping to sweet potatoes, some of these soils have become highly acid, with a pH below 4.9 *(7)*. This is an undesirable reaction of the soil from many standpoints of plant nutrition, and certain other crops, such as cotton, tomatoes, and soybeans, are known to suffer from manganese phytotoxicity under highly acid conditions on a Mississippi terrace soil *(33, 38, 44)*. It is well-known that this group of soils is relatively high in total manganese content (*44*). Under moderately acid conditions only a small percentage of the total manganese present is soluble; however, as the soil becomes more acid the solubility of the manganese-bearing salts increases so that additional amounts of manganese may be taken up and accumulated by plants to a point at which toxicity occurs. Therefore, since different plant species have different tolerance levels to manganese in the foliage (*12, 16, 25*), and since no information was available on the question of manganese toxicity in sweet potatoes, and since some sweet potato growers are using highly acid terrace soils for their crop while others are using terrace or Loessial Hill soil that has been limed, it appeared desirable to study the influence of soil reaction in a typical Mississippi terrace soil on the growth and production by sweet potatoes. Quality studies were incorporated into this project in 1967 to determine the effects of soil pH and fertilization on the quality of fresh and processed sweet potatoes.

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[2] Italic numbers in parentheses refer to Literature Cited, page 52.

Review of Literature

The use of sulfur as a soil amendment for controlling sweet potato soil rot, caused by *Streptomyces ipomoea,* has been reported by several investigators (*17, 19, 34, 35, 36*). Sulfur applied in the proper amounts lowers the soil pH to a point at which the soil rot organism will not grow (*34, 35*). However, with the lowering of the soil pH many changes take place in the nutrients in the soil, among which is a marked increase in the solubility of soil manganese, iron, and aluminum (*40, 45*). The increased solubility of these elements can cause a sharp increase in their absorption and accumulation rates by crop plants resulting in phytotoxicity (*5, 16, 22, 27, 30, 33, 40, 41*). This is particularly true for the element manganese. Neal and Lovett found manganese toxicity in cotton growing on Mississippi River terrace soils in Louisiana in which the reaction had decreased to values below 5.0 (*33*). They called the condition ''crinkle-leaf'' and stated that it occurred fairly commonly in cotton grown on acid terrace or Loessial Hill soils (*33*). A similar situation has been noted with tomatoes and soybeans grown on highly acid terrace or Loessial Hill soil, in which case the manganese toxicity is shown as a characteristic chlorotic pattern in the leaves (*38, 44*).

Evidently, different plant species have wide differences in their tolerance to manganese accumulation in the tissue before showing symptoms of phytotoxicity (*1, 5, 6, 13, 14, 16, 25, 29, 30, 31, 32, 33, 36, 37, 38, 39, 46*). Little information is available on the level of manganese necessary to cause toxicity in sweet potato foliage, although it has been established that a certain level of the element in the foliage is necessary for normal growth and production (*9, 31*).

The use of lime as a soil amendment for sweet potatoes is not a common practice, even though the crop is often grown on low-calcium, moderately acid soil. Several investigators have found the calcium requirement of sweet potatoes to be relatively low (*4, 8, 9, 10, 15, 42*). In experiments by Cibes (*9*), Edmond (*10*), and Spence (*42*) under controlled conditions in which the supply of nutrients was precisely regulated, sweet potato plants grown under a very low calcium regime made good growth and yields comparable to those of the control. In field experiments on a Providence silt loam soil low in native calcium supply (240 ppm), Balerdi (*4*) obtained no response in growth, yield, or calcium uptake to applications of calcium carbonate, sulfate, or chloride. However, in a greenhouse study with a Stough very fine sandy loam containing only 32 ppm of calcium as native supply, he noted marked responses in plant growth and color to calcium applied in the acetate form (*4*). In a field test, Steinbauer and Beattie (*43*) studied the effects of hydrated lime and calcium chloride applied annually to a soil with an original pH of 4.6 to 5.0. After 5 years of work, they concluded that sweet potatoes are tolerant of a wide range in soil pH but grow best and produce highest yields on slightly to moderately acid soil, with yield reductions on alkaline soil. In other studies with sweet potatoes in the field by Jones (*23*), very good plant growth and high yields have been produced on the lighter-textured soils of the Mississippi River and Red River alluvial areas with a high native calcium supply (2,000 to 3,000 ppm) and a high pH (7.0 to 7.5). Conversely, additional experiments located on moderately acid Mississippi River terrace or Loessial Hill soils (pH of 5.0 to 6.0) with a low native calcium supply (400 to 800 ppm), or on Coastal Plain soils of similar reaction and calcium supply, have resulted in very high yields of good quality sweet potatoes in most cases (*23*).

Materials and Methods

This study was begun in 1960. It was located at Chase in Northeast Louisiana on Grenada silt loam (formerly identified as Olivier silt loam), a prominent soil in the Loessial Hills and Mississippi Terrace soil area in Louisiana. Somewhat similar soils in the same area include the Calloway, Loring, and Olivier silt loams. The soil had previously been used for general farming purposes for many years prior to its use for experimentation. A representative sample of the soil used in this work showed that it was acid in reaction with a pH of 5.2.

An experimental area 72 feet wide and 205 feet long was used for this study. This area consisted of six blocks 30 feet long with 5-foot alleys between blocks. Each block was divided into six treatment plots, each plot being 12 feet wide and 30 feet long. Before any treatments were applied, a representative sample was taken of the topsoil and subsoil from each treatment plot. Subsequently, soil amendment and fertilizer treatments were applied to the plots, which were arranged in a Latin square design. By way of preparation, the soil was disked down completely flat. The appropriate amount of lime or sulphur was applied evenly over the surface of each plot, and the material was thoroughly disked into the soil. These amendments were applied in March of each season through the 1971 season, and the soil was allowed to remain flat for about 2 months following application of the amendments. In May the soil was bedded up into rows 4 feet wide and fertilizer was applied to those plots designated to receive it. The fertilizer used consisted of 30 pounds of nitrogen, 60 pounds of phosphate, and 30 pounds of potash during the 1960-70 seasons and 30-60-60 in 1971-73. Each plot consisted of three rows 30 feet long. Planting of the plots was done in May, using slips of Goldrush during the first year and Centennial each year thereafter except in 1971, when the seedling L4-89 was grown, and in 1972, when seedling L4-186 was used. Plants were spaced approximately 12 inches apart by use of a mechanical two-row transplanter. The herbicide Enide was applied to the tops of the rows at the rate of 6 pounds (active ingredient) per acre immediately after planting, and during the early part of the growing season the water furrows were cultivated as necessary to control weeds. A stand count was taken at about 2 weeks after planting. Irrigation water was applied as necessary to get good growth and production. During the growing season in some years, representative samples of the foliage and soil were taken periodically from the center row of each plot for analysis in the laboratory. The results of these analyses appear in some of the following tables.

The plots were harvested in September or October each year. At harvest, only the roots from the center row were used for records, and the roots were graded into classes of Number 1, Number 2, or Cull, according to U.S. Department of Agriculture standards. The weight of each grade was determined and recorded by plot. The roots from each plot were transported to Baton Rouge for evaluation as to incidence and severity of disease infection. Once this was accomplished, the roots were analyzed and processed. The analyses consisted of dry matter and carotenoid pigment determinations, and the processing procedure involved canning and later evaluating the quality of the pack.

At harvest 10 roots from each plot were cut longitudinally, one-half being used for flesh color analyses and the other half for dry matter determinations. Duplicate 10- to 12-gm. samples of grated tissue to be used for dry matter determinations were dried for 24 hours at 80°C. in a forced-air oven. After drying, the samples were ground to pass through a 40-mesh screen in a Wiley mill and were subjected to fiber and protein analyses according to Association of Official Agricultural Chemists procedures (*3*).

Optical densities (flesh color) of 0.1 gm.-samples of tissue homogenized with 10 ml. of hexane were determined at 440 mu with a Beckman DB-G recording spectrophotometer. Carotenoid content was determined by comparison with a Beta-carotene standard curve. Duplicate color samples were tested from each plot. Flesh color of canned sweet potatoes was determined as for fresh potatoes, with the exception that benzene was used as the solvent.

Canning grade roots were processed 1 to 2 days after harvest. Standard canning procedures were followed and consisted of lye peeling in 10 percent sodium hydroxide at 218° F., washing, trimming, filling the cans with hot 30 percent cane sugar syrup, exhausting until the center can temperature reached 180° F. (about 3½ minutes), sealing, and retorting for 35 minutes at 240° F. After water cooling, the canned potatoes were stored at room temperature for at least 3 months before evaluation.

Firmness of canned sweet potatoes was determined by use of a Food Technology Corporation shear press with recorder, utilizing a 250-pound proving ring, 200 gms. of sweet potatoes in a 10-prong standard shear cell, and a 30-second stroke at 100 pounds of pressure.

Data were also obtained on "cracking" or "splitting" of the roots in the cans. Total root count was taken along with total "splits" and "severe splits" (roots that would be expected to fall apart upon shipping).

In taking samples of the foliage during the growing season, the leaves were sampled in each plot by position from the terminal bud. Each visible leaf was counted, whether opened or not, starting at the terminal of the vine. Leaves number 6, 10, and 14 were the ones most frequently sampled, but in some cases leaves were taken from other positions on the vine. Within a 30-plant plot, every other hill was sampled, with only one representative vine from the hill being used in the sample. Once a leaf was taken from a certain position on the vine it was combined with the 14 other leaves from that same position taken within a plot. Thus, each foliar sample consisted of 15 leaves taken from the same position on different vines in the same plot. Each leaf collected was rated for the presence and severity of chlorotic symptoms by comparison with a previously-prepared standard. The leaves were then thoroughly washed in tap water and distilled water and dried in a forced-air oven at 65° C. for 24 hours. After drying, the leaves were ground fine enough to pass through a 20-mesh screen in a stainless steel Wiley mill and used for chemical analyses.

At harvest time, six Number 1 and six Number 2 roots within a plot were composited for dry matter determinations and certain other chemical analyses. A 10-gram sample of the freshly ground tissue was taken for the dry matter measurement. The remainder of the ground roots were dried in a forced-air oven at 65°C. and ground fine enough to pass through a 20-mesh screen in a Wiley mill. This tissue was used for chemical analyses.

In analyzing either leaf or root tissue, a 1-gram sample was weighed into a Gooch crucible and ashed in a Blue M Electric Co. Model M25A muffle furnace for 4 hours at 550° C. Then 10 ml. of a 50 percent HC1 solution was used to dissolve the ash. This solution was heated until it cleared up and then filtered throughWhatman No. 2 filter paper. The filter paper was washed with hot water several times, and the volume was made up to 100 ml. with distilled water, giving a 1:100 sample dilution. From this solution, the manganese and magnesium contents were determined on a Perkin-Elmer Model 303 atomic absorption spectrophotometer. The calcium content was determined on a Beckman Model D. U. flame spectrophotometer in 1969 and on the atomic absorption spectrophotometer in 1970. Aluminum was determined colorimetrically by a modified aluminon method (*46*). Iron was determined by the orthophenanthroline method (*2*), and phosphorus was determined by the vanadate method (*2*).

In the soil analysis work, the pH was determined by using a 1:1 soil/water mixture and allowing it to stand overnight (*7*). The pH value was determined with a Corning Model 10 pH meter.

A 5-gram sample of soil was extracted with 50 ml. of a 1 N ammonium acetate solution buffered at a pH of 4.8 to determine manganese, iron, aluminum, calcium, and magnesium contents (*11, 18, 20, 28, 48, 49*). The method used, described by Jackson (*21*), involved weighing out 5 grams of soil into a centrifuge tube and then adding 25 ml. of the extracting solution. The centrifuge tube was stoppered and shaken on a mechanical shaker for 30 minutes. The samples were then centrifuged at approximately 3,000 rpm for 5 minutes. The supernatant liquid was poured onto Whatman No. 2 filter paper and collected in a 50 ml. volumetric flask. Then 25 ml. of the extracting solution was added to the centrifuge tube. It was then stoppered and shaken for 10 minutes, centrifuged for 5 minutes, and filtered. The volumetric flask was filled to volume with extracting solution. The manganese and magnesium contents of the sample were determined on a Perkin-Elmer Model 303 atomic absorption spectrophotometer. The calcium content was determined on a Beckman Model D. U. flame spectrophotometer in 1969 and on the atomic absorption spectrophotometer in 1970. Aluminum was determined colorimetrically, using a modified aluminon method described by Vogel (*46*). Iron was determined colorimetrically, using the dipyridyl method described by Kumada (*24*).

All other soil samples were analyzed by the Louisiana State University Soil Testing Laboratory, using well-known methods of analysis (*7*).

Beginning in 1965, data were obtained on soil rot severity in each of the experimental plots. During the growing seasons of 1965, 1966, and 1970, ratings were made of vine growth on plants in the center row of each plot 7 to 9 weeks after planting according to the following scale: 1 = poor vine growth with most of the plants severely stunted; 2 = fair vine growth but clear evidence of some effects of disease or chemical injury; 3 = good vine growth with little or no evidence of disease; 4 = very good, vigorous vine growth. These data were analyzed statistically, considering amendments and fertilizer as fixed effects and years as random effects. At harvest, each sweet potato was placed into one of the following five soil rot severity classes: 0 = none, 1 = trace, 2 = slight, 3 = moderate, and 4 = severe. From these data the percentage of sweet potatoes affected by soil rot was determined, and a soil rot severity index was calculated for each plot by the following formula:

$$\frac{\text{Sum of (No. of potatoes in each class x class No.)}}{\text{(No. of potatoes classed) x (No. of classes} - 1)} \text{ x } 100 = \text{severity index}$$

Thus, if all sweet potatoes were free of soil rot and were placed in 0 class the severity index would be 0, and if all sweet potatoes had only a trace of soil rot and were placed in class 1 the severity index would be 25, and so on, until finally if all sweet potatoes were severely affected with soil rot and were placed in class 4 the severity index would be 100.

The combined data for the 7 years 1965-1970 and 1973, when the Centennial cultivar was planted, were analyzed statistically for both the percentage of sweet potatoes affected by soil rot and soil rot severity indexes. In the analyses, amendments and fertilizer were considered as fixed effects and years as random effects. The data for 1971 and 1972 were omitted from the combined analyses because a moderately resistant (L4-89) and a resistant (L4-186) cultivar were planted, respectively, during the 2 years.

Results and Discussion

Each of the soil amendments applied had a rather pronounced effect upon the soil reaction, as shown in Figure 1. The application of sulfur had a depressing effect on the soil pH, beginning with the first year of application and continuing throughout the experimental period. This effect tended to disappear during the last two seasons when no soil amendments were applied to any of the plots. The pH of the sulfur-treated soil, initially at 5.2, dropped to levels well below 5.0 and in some cases reached a low point of 4.4 as the seasons passed. Except for 1964 and 1965, the use of fertilizer with the sulfur application had little bearing on the acidifying effect of the amendment.

Conversely, the addition of lime to the soil reduced the soil acidity (increased the pH) from the first year on throughout the experimental period (Figure 1). In fact, this amendment had changed the reaction of the soil from an initial pH value of 5.2 up to the point of neutrality (7.0) by the end of the sixth season. Beyond that season, the pH remained at or near neutrality for the remainder of the experimental period. Again, as was the case with sulfur applications, the effect of lime on soil pH tended to fall off during the last year when no additional lime was used on the soil. With this amendment, the use of fertilizer showed a tendency to lower the soil pH fairly consistently. (In formulating the fertilizer used, ammonium nitrate, ordinary superphosphate, and muriate of potash were used as nutrient carriers.)

The reaction of the soil which did not receive any amendment showed little change during the first few years, but during the later years of the experiment a gradual rise in the pH was indicated (Figure 1). This change in the pH was not expected and cannot be explained on the basis of border effect, since all plots were well-guarded and every precaution was taken during all field operations not to mix the soil from one plot with that of another one. Furthermore, all soil and plant samples were taken only from the center row of each 3-row plot. In this case again, the application of fertilizer resulted in a lower soil pH than that of unfertilized soil.

The influence of soil amendment and fertilizer applications on the level of extractable phosphorus from the soil is shown in Figure 2. During the first few years of the study, there was no clear-cut relationship between experimental treatment and phosphorus level, but as the seasons passed a definite trend gradually emerged indicating that all of the plots receiving fertilizer applications contained more extractable phosphorus than those not receiving fertilizer. During the later years, among the fertilized plots there were no consistent differences in phosphorus content due to the type of soil amendment used. Among the unfertilized plots, which were much lower in extractable phosphorus, only questionable differences occurred as a result of soil amendment use. Thus, it was apparent that fertilizer

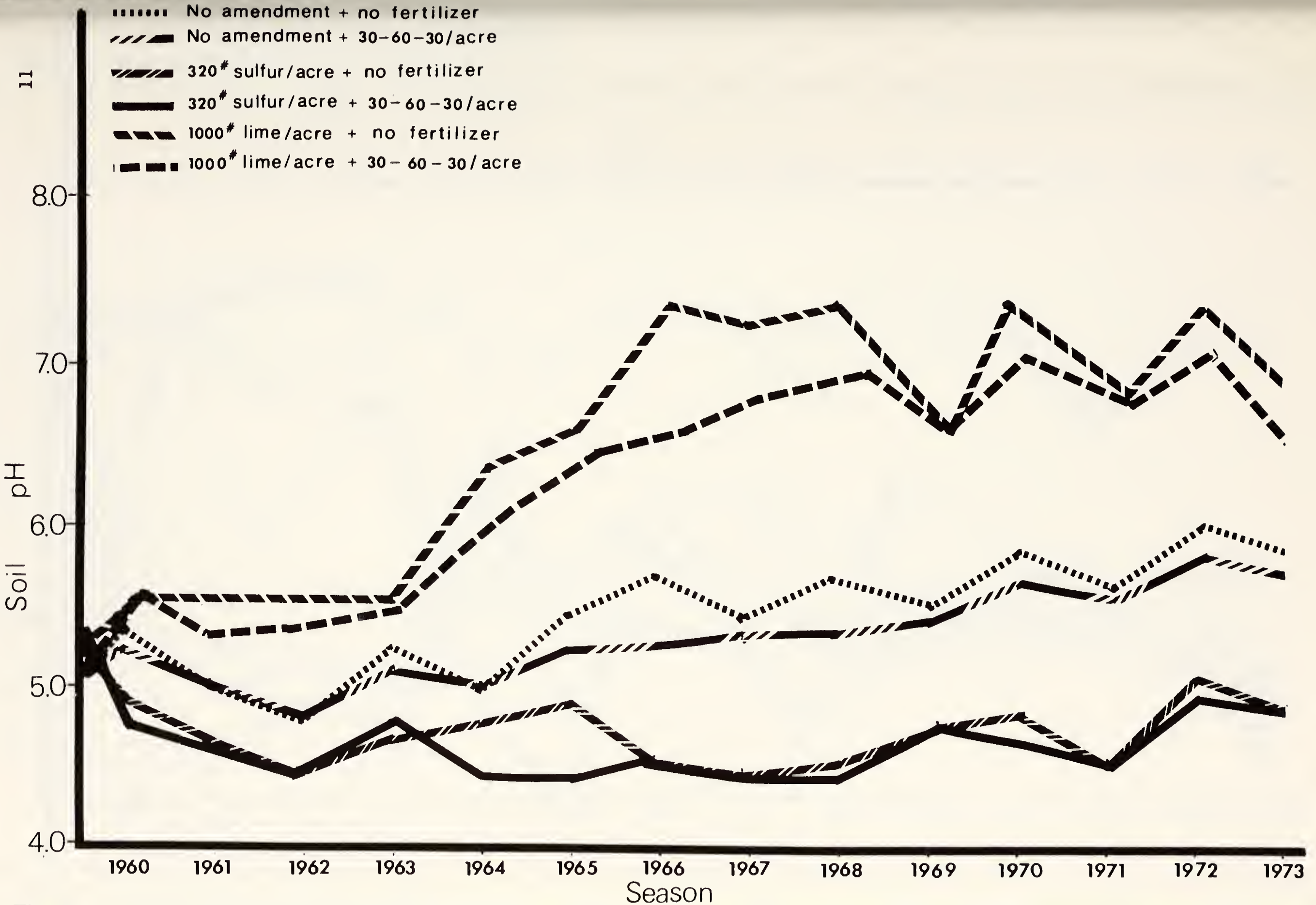

Figure 1. — The reaction of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

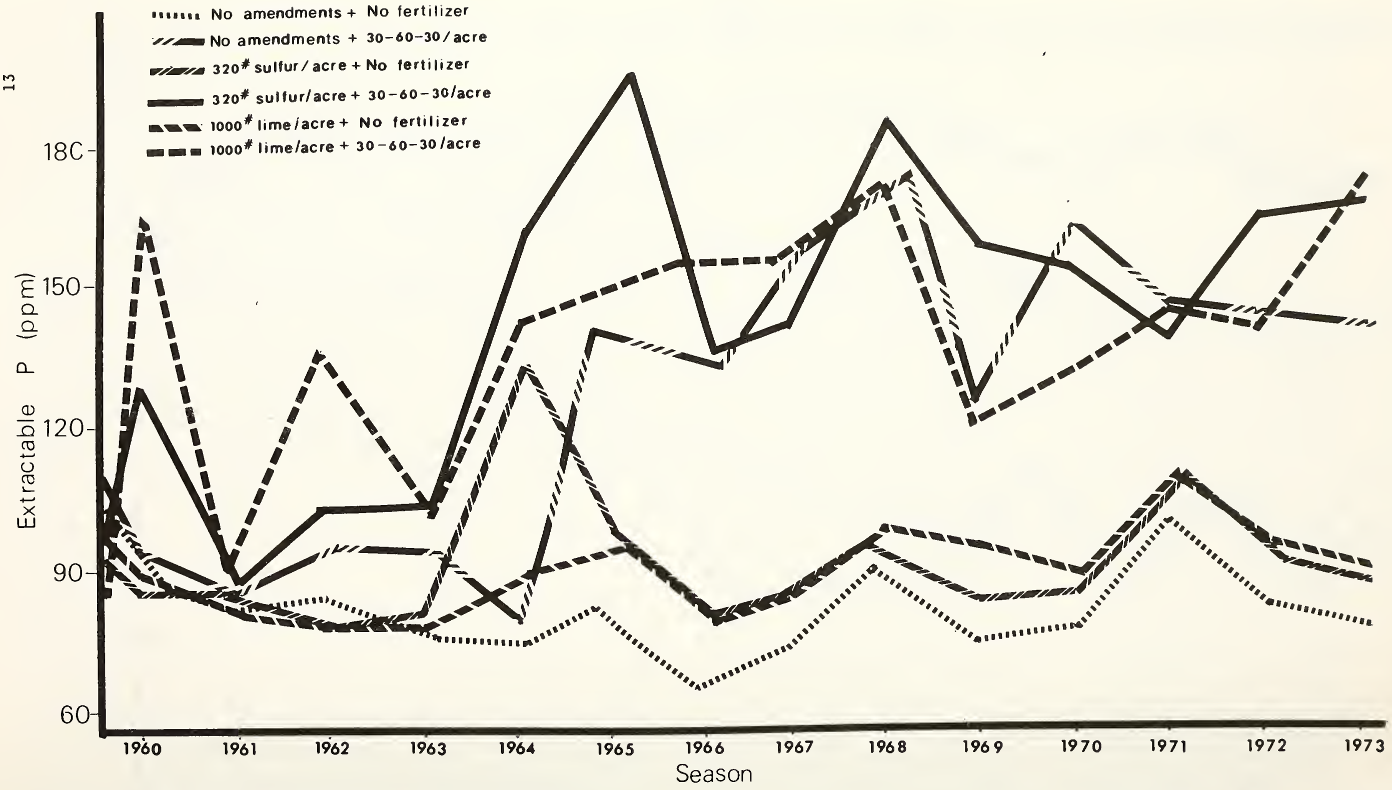

Figure 2. — Extractable phosphorus content of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

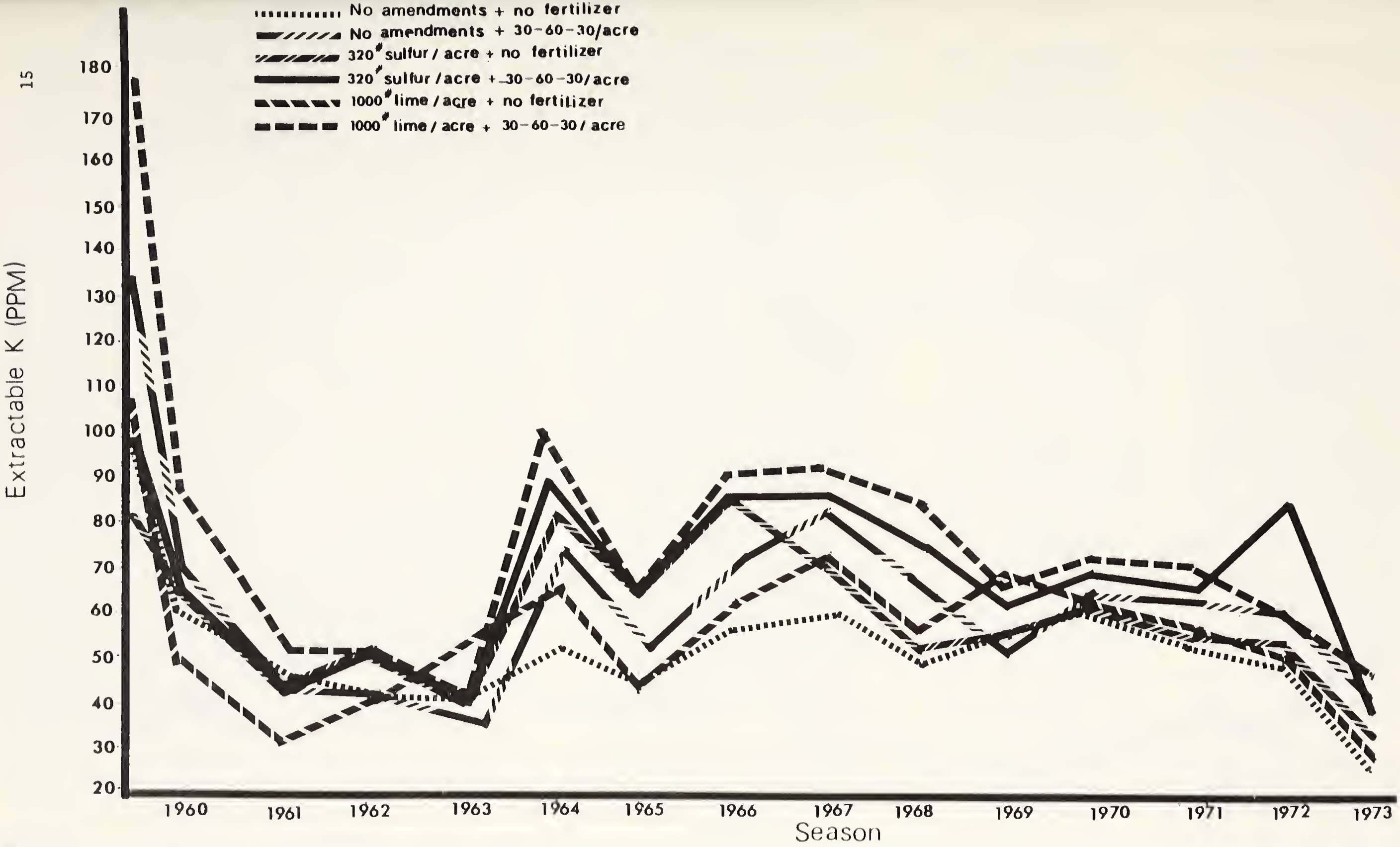

Figure 3. — Extractable potassium content of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

applications were responsible for much larger differences in extractable phosphorus from the soil than was the use of these two soil amendments, even with their pronounced effects upon the soil reaction shown in Figure 1. At the end of the experimental period, all of the plots having received fertilizer applications were considerably higher in extractable phosphorus content than they were at the outset of the experiment. On the other hand, the unfertilized plots were somewhat lower in phosphorus than they were in the beginning.

The extractable potassium in the soil was not strongly affected by soil amendment or fertilizer applications, as shown in Figure 3. A rather pronounced decrease was indicated in all plots during the growing season of 1960. After that, the potassium level remained fairly even throughout the experimental period, with no definite accumulation being indicated in the fertilized plots. In the last year, 1973, the soil was much lower in extractable potassium in all plots than it was at the beginning of the experiment.

The extractable calcium level in the soil was markedly affected by soil amendment applications (Figure 4). The effect of lime applications was first shown during the initial few years of the study, and the peak in calcium accumulation was reached at the 1966 season. Following that, no further buildup of extractable calcium was indicated in the lime-treated soil. The use of sulfur apparently depressed the concentration of extractable calcium in the soil, this response being manifested after the first few applications of sulfur and lasting throughout the remainder of the study, with one inconsistency indicated in the 1964 season. Little difference in soil calcium could be attributed to the use of fertilizer, regardless of the amendment applied.

Differences in extractable magnesium followed a pattern similar to that of calcium (Figure 5). Lime applications increased the magnesium levels while sulfur applications decreased them throughout the period. Again, the use of fertilizer had little effect on extractable magnesium levels.

The interrelationships of soil reaction to various other soil factors over the entire 14-year period are presented in Table 1 in the form of correlation coefficients. The level of extractable phosphorus did not show a close dependence on the soil pH, and potassium extractability was not related to soil reaction in any way. On the other hand, both calcium and magnesium were extractable in proportion to rises in the soil pH value. Further, these two elements were positively related to each other in their extractability from the soil. Conversely, extractable calcium had little influence on the amount of potassium extracted from the soil, nor did magnesium have any effect on this process.

The data in Table 2 show that the plant stand of sweet potatoes was not materially affected by either the soil amendments or fertilizer applied over the 14-year experimental period. Only in the 1965 season was there any

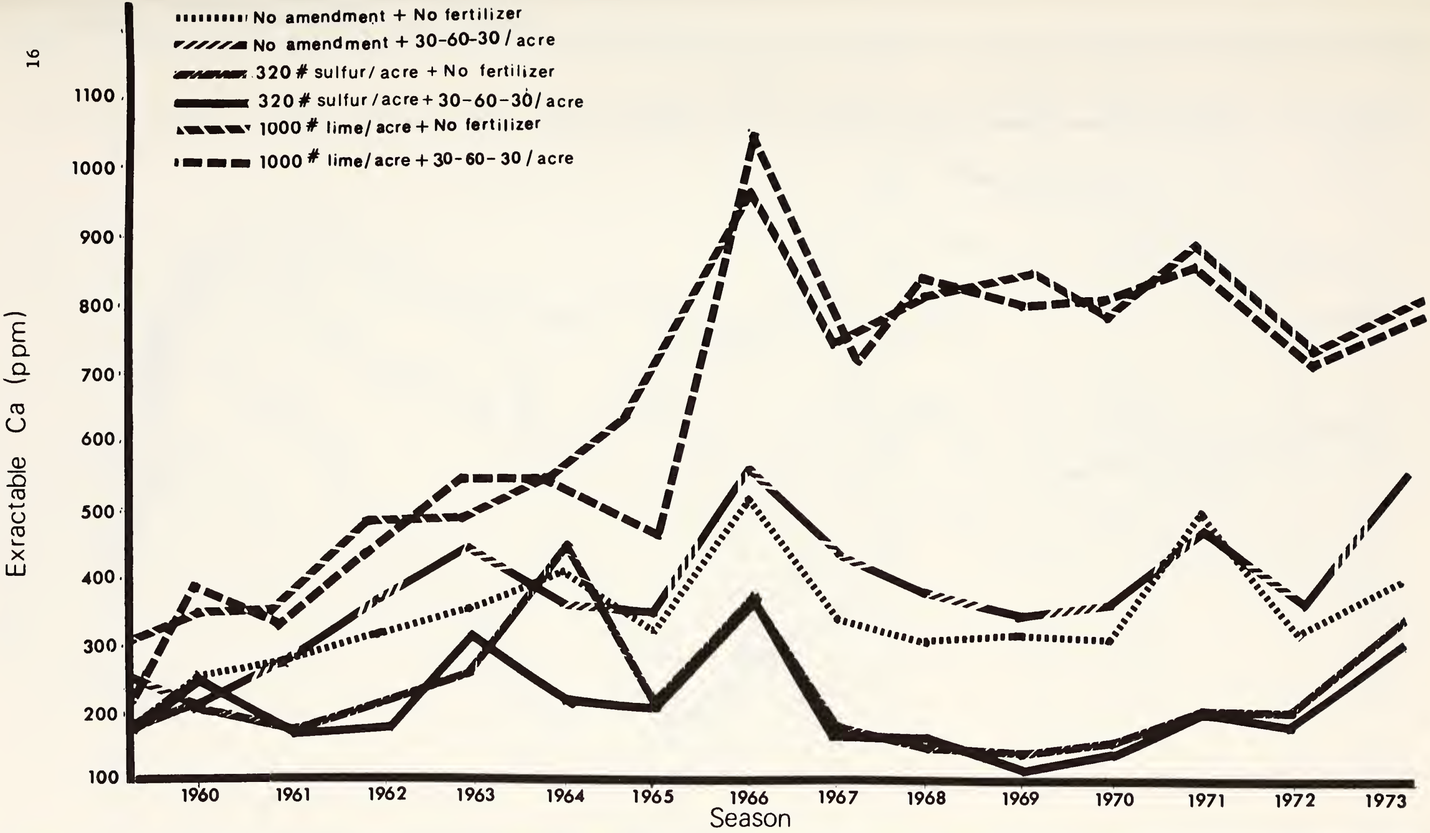

Figure 4. — Extractable calcium content of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

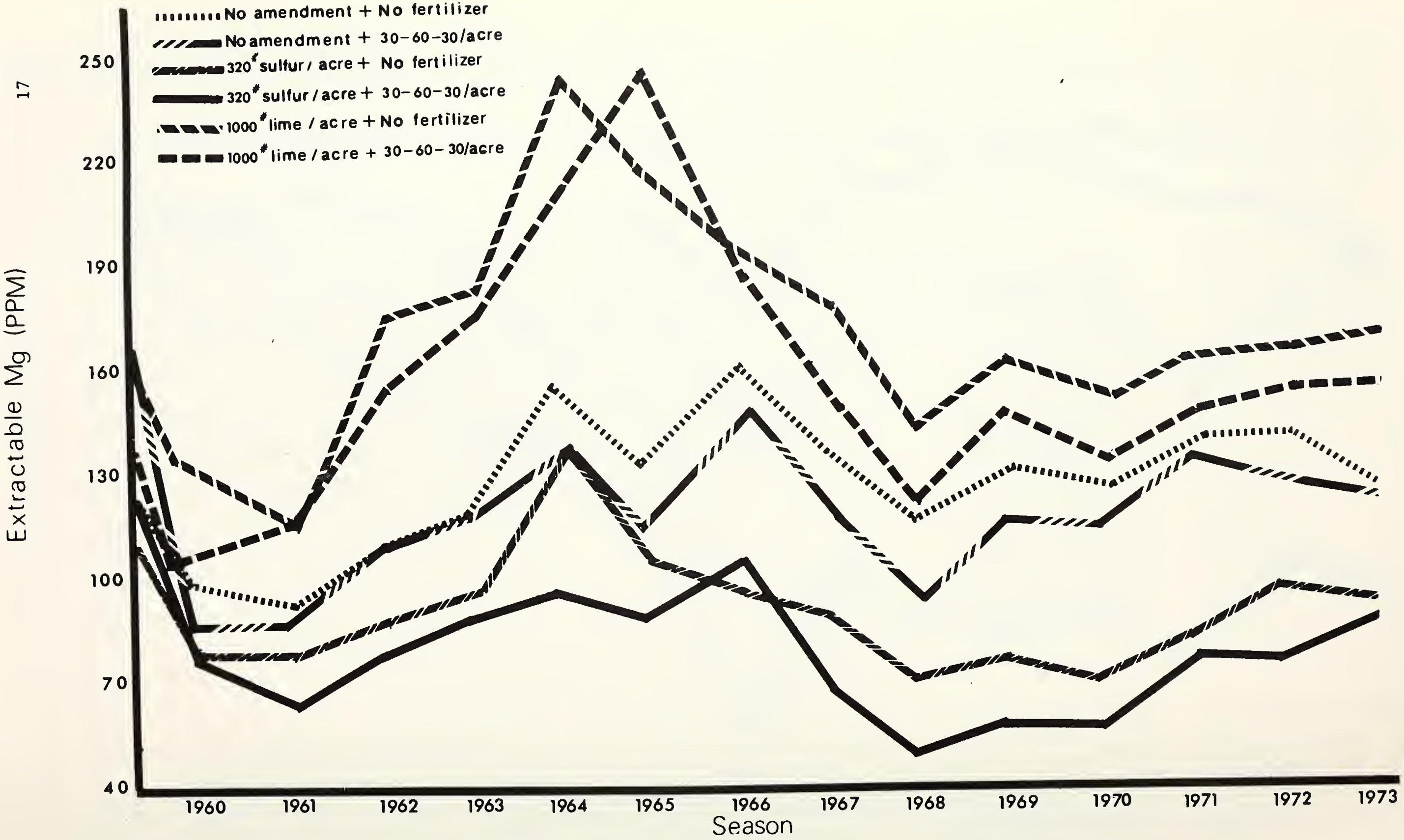

Figure 5. — Extractable magnesium content of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

Table 1. — The relationship between the soil reaction and the levels of extractable* phosphorus, potassium, calcium, and magnesium during the 14-year period, 1960-73

Soil Variables	r Value
Soil pH with Extractable Soil Phosphorus	0.44**
Soil pH with Extractable Soil Potassium	-0.002
Soil pH with Extractable Soil Calcium	0.87**
Soil pH with Extractable Soil Magnesium	0.71**
Extractable Soil Calcium with Extractable Soil Magnesium	0.83**
Extractable Soil Calcium with Extractable Soil Potassium	-0.04
Extractable Soil Magnesium with Extractable Soil Potassium	0.04

*Extracted with 0.1 N HCl at a soil:extractant ratio of 1:20 except for phosphorus in which case 0.03 N NH_4F was included in the extractant.

**Significant at the .01 level of probability.

real indication of a difference in plant stand due to treatment. This indication appears of minor consequence in view of the remainder of the data indicating no relationship between experimental treatment and plant stand. The stand during the first year was poor in all plots. This result was ascribed to dry soil and warm weather at planting time, along with the recognized tendency of the Goldrush cultivar to give poor stands when planted under adverse conditions. The following year and for the next 9 years the Centennial cultivar was substituted for Goldrush, and a good plant stand was obtained in all plots. In the 1971 season, the seedling L4-89, which is resistant to the soil rot organism, was planted instead of Centennial to study the possible response by this variety to a ''high-calcium, high-pH'' soil. A good stand was obtained with no association between treatment and stand present. Another seedling, L4-186 which is highly-resistant to soil rot, was planted in all plots in the 1972 season. Again, a very good stand resulted in all plots. Then in the 1973 season, the Centennial variety was used again and, as in previous years, showed an almost perfect stand in all plots.

The effects of the soil amendments and fertilizer on the production of Number 1 grade sweet potatoes are presented in Table 3. During the first year with the Goldrush cultivar, none of the combinations of amendment and fertilizer was beneficial in terms of yield. The most noticeable result was the depression in yield by sulfur applications. In the following year when Centennial was planted, the yields were increased by the use of fertilizer, with an additive effect being indicated between lime and fertilizer. These results, although not significant, were shown again in the 1962 season except for the low yield where sulfur and fertilizer were both applied. In 1963 the pattern changed somewhat in that production from the limed soil showed a downward trend. This was brought about by the beginning of infection of some of these potatoes with soil rot which relegated these particular roots into the Cull class. By the 1963 season the

Table 2. — The stand of sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

	No. of Plants/Acre														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment- No Fertilizer	6,534	9,801	9,620	8,469	8,894	11,315	11,253	11,315	11,616	11,435	10,465	9,195	10,770	10,647	10,095
No Amendment 30-60-30/A[3]	6,353	9,500	9,739	8,469	8,774	11,373	11,072	11,554	11,736	11,435	10,709	9,318	10,709	10,890	10,117
320# S/A - No Fertilizer	5,688	9,620	10,044	8,832	8,531	11,191	11,435	11,798	11,496	11,315	10,647	9,400	11,072	11,315	10,170
320 # S/A - 30-60-30/A[3]	5,870	9,739	10,102	8,531	8,774	11,373	11,315	11,678	11,072	11,253	10,770	9,137	11,373	11,072	10,147
1,000# Lime/A[4] No fertilizer	6,534	9,801	9,921	8,531	8,774	11,315	11,373	11,554	11,616	11,496	10,589	8,955	11,010	10,952	10,173
1,000# Lime/A[4] 30-60-30/A[3]	5,870	9,681	10,044	8,531	8,955	11,796	11,191	11,554	11,736	11,435	10,465	9,137	10,952	10,952	10,164
LSD (.05)	NS	NS	NS	NS	NS	465	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD (.01)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, and Centennial in 1973; planted in May each year and harvested in September.

[2] Applied broadcast in March the first 11 years, then none thereafter.

[3] The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4] Dolomite applied the first 5 years, then calcite the next 6 years, then none.

Table 3. — Yield of Number 1 sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Number One Roots (Bu./Acre)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment-No Fertilizer	329	298	336	166	107	140	201	111	91	80	146	82	39	73	159
No Amendment - 30-60-30/A[3]	302	336	387	248	145	142	380	177	143	152	235	171	73	114	215
320# S/A - No Fertilizer	209	292	328	138	127	132	301	142	284	144	132	65	51	107	168
320# S/A - 30-60-30/A[3]	242	350	292	232	104	157	336	220	221	138	161	136	60	198	203
1000# Lime/A[4] - No Fertilizer	334	329	349	167	74	52	70	30	17	17	90	114	68	31	124
1000# Lime/A[4] - 30-60-30/A[3]	301	408	396	201	88	94	151	73	31	56	122	150	90	84	160
LSD (.05)	83	65	NS	52	NS	NS	79	49	37	51	55	42	26	52	47
LSD (.01)	114	NS	NS	71	NS	NS	107	67	51	69	75	57	NS	70	65

[1] Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, and Centennial in 1973 - planted in May each year and harvested in September.

[2] Applied broadcast in March the first 11 years, then none thereafter.

[3] The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4] Dolomite applied the first 5 years, then calcite the next 6 years, then none.

pH of the soil in the limed plots had reached a point around 5.5 (Figure 1). Additional presentation of results and discussion of the extent of soil rot infection undergone by the roots from each of the plots in the experiment are given later in this bulletin. In the 1963 season, the beneficial effects of fertilizer were shown with each amendment treatment. The fertilized plots not receiving any amendment showed some indication of superiority. (Reference to Figure 1 will also show that the sulfur-treated plots had become highly acid by the 1963 season.) During the next two seasons, the yields were low from all plots with the greatest depression in the limed plots due primarily to a high percentage of the roots being infected with soil rot. In 1966, the yields were back up to more normal levels. The use of fertilizer was beneficial to each amendment treatment; however, the amendments even applied with fertilizer reduced the yield below that of the control. The inferiority of the limed soil was clearly shown.

For the remainder of the experimental period, 1966-73, the data indicated, with some exceptions, that the use of sulfur as an amendment was of no benefit to yield, especially when used in conjunction with fertilizer. Further, the use of lime was definitely detrimental to production of Number 1 potatoes, whether it was used with fertilizer or not, because of continued infection of the roots by the soil rot organism. The highest yields and the best plant growth were obtained from fertilized soil which had not received any amendment application.

In the 1971 season when the seedling L4-89 was grown, the detrimental effects of the lime amendment were greatly reduced, since the soil rot organism does not affect this seedling to any great extent. However, there was no indication of a benefit from lime applications as was noted during the first few years of the experimental period, presumably before the soil rot organism had time enough to build up a sufficient population to cause significant damage to the crop. Conversely, the use of sulfur caused a greater reduction in yield than the use of lime in this season.

During 1972, the yields by plants of the L4-186 seedling were so low that it was considered inappropriate to draw any inferences from the data obtained.

In 1973 when Centennial was planted again, the detrimental effects of lime were clearly demonstrated once more. It may be recalled that no amendments had been applied to the soil since 1970, but Figure 1 shows that the limed soil still had a pH value of about 6.5, one that favors the growth and activity of the soil rot organism.

The yield of Number 2 potatoes as affected by soil amendment and fertilizer is presented in Table 4. As was the case with Number 1 roots, these yields varied considerably from season to season. Although the differences in yield were significant within certain seasons, they were not significant in others, and no over-all patterns of treatment effects were established. A definite sign of yield depression was shown in the center

Table 4. — Yield of Number 2 sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Number Two Roots (Bu./Acre)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment-No Fertilizer	42	120	98	183	168	40	74	23	27	71	60	29	31	34	71
No Amendment - 30-60-30/A[3]	31	113	55	188	190	41	70	22	35	129	59	39	31	36	74
320# S/A - No Fertilizer	36	127	79	186	150	27	42	41	38	88	39	38	33	62	70
320# S/A - 30-60-30/A[3]	28	97	69	139	160	25	60	24	51	85	39	35	31	65	65
1000# Lime/A[4]-No Fertilizer	42	114	99	126	110	11	13	1	4	16	31	44	36	15	47
1000# Lime/A[4] - 30-60-30/A[3]	28	109	78	157	180	13	85	11	8	96	51	40	34	25	65
LSD (.05)	16	NS	26	NS	50	20	33	15	23	44	NS	NS	NS	25	16
LSD (.01)	22	NS	NS	NS	NS	NS	45	21	31	61	NS	NS	NS	34	22

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[1] Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, Centennial in 1973 - planted in May each year and harvested in September.

[2] Applied broadcast in March the first 11 years, then none thereafter.

[3] The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4] Dolomite applied the first 5 years, then calcite the next 6 years, then none.

portion of the experimental period in the limed plots, especially those without fertilizer. This was related to the development of soil rot lesions in the roots from these plots. During the 1971 and 1972 seasons when the soil rot resistant seedlings were grown, there was no indication of a yield depression caused by the application of lime.

The production of Cull grade potatoes was markedly affected by soil amendment and fertilizer applications (Table 5). During the first several years, differences in yield were either small or not consistently associated with treatment, but by the 1963 season when production of Number 1 roots began to decline in the limed soil (Table 3), the yield of Cull roots began to increase in the same plots (Table 5). Beginning in 1964, the limed plots receiving fertilizer consistently produced more Cull grade roots than any other plot, as long as Centennial was used as the test cultivar. Ranking second were the plots receiving fertilizer but no amendment. The sulfur-treated soil produced relatively few Culls, whether the soil was fertilized or not. The soil receiving no fertilizer or amendment and that receiving lime but no fertilizer produced intermediate yields of Cull roots. The two soil rot resistant seedlings, L4-89 and L4-186, showed little response to amendment treatment but did indicate some response to fertilizer application (Table 5).

The total yield of sweet potatoes was affected to some extent by soil amendment and fertilizer applications (Table 6), but moreso in some seasons than in others. In the first year with Goldrush, a depressive influence was shown by sulfur application, with or without fertilizer. The use of lime tended to increase the yield, especially when applied with fertilizer. In the next season when Centennial was used, the depressing effect of sulfur was not found, but a tendency was still shown by lime applications to increase the yield. This was also true for fertilizer used with each amendment. During the following year (1962), the results from the limed plots were the most outstanding while production from the sulfur-treated was lowest. Then in 1963, the picture began to change as production from the limed plots started to decrease and that from the plots receiving no amendment began to increase with respect to each other. Data in Table 3 indicate that the yield of Number 1 potatoes showed a similar pattern and was related to a gradual increase in the development of soil rot in the roots produced by the limed plots (Table 5). By the following year, 1964, the limed soil was definitely depressing the yield, as was the sulfur amendment. This trend continued over the next 6 years, with the plots receiving fertilizer but no amendment being clearly superior to the others. During this period, the beneficial effects of fertilizer were shown with all amendment treatments. The lowest yield was obtained from the limed plots receiving no fertilizer. During the seasons of 1971 and 1972 the yields by the soil rot resistant seedlings were not depressed by the limed soil, nor were they increased by it. With the L4-89 a yield depression was indicated

Table 5. — Yield of Cull sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Cull Roots (Bu./Acre)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment-No Fertilizer	83	70	59	80	36	91	73	192	111	74	51	90	157	82	89
No Amendment - 30-60-30/A[3]	109	60	85	44	35	122	40	325	211	108	142	108	178	168	124
320# S/A - No Fertilizer	79	77	50	68	13	71	38	122	62	60	50	79	160	59	71
320# S/A - 30-60-30/A[3]	75	69	74	30	18	63	36	152	57	91	48	85	223	87	79
1000# Lime/A[4]-No Fertilizer	99	64	55	127	74	108	45	311	169	46	67	86	177	50	105
1000# Lime/A[4] - 30-60-30/A[3]	158	53	68	64	70	170	99	380	276	158	212	123	168	140	153
LSD (.05)	36	NS	NS	55	34	45	40	69	32	19	49	NS	NS	40	35
LSD (.01)	49	NS	NS	NS	46	61	NS	94	44	26	67	NS	NS	55	49

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[1] Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-86 in 1972, Centennial in 1973 - planted in May each year and harvested in September.

[2] Applied broadcast in March the first 11 years, then none thereafter.

[3] The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4] Dolomite applied the first 5 years, then calcite the next 6 years, then none.

Table 6. —Total yield of sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Total Yield (Bu./Acre)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment-No Fertilizer	457	485	493	428	311	271	347	327	229	225	258	201	221	189	317
No Amendment - 30-60-30/A[3]	445	509	527	479	370	305	490	524	388	390	436	317	282	318	413
320# S/A - No Fertilizer	324	495	456	392	290	230	381	293	281	293	220	182	243	228	308
320# S/A - 30-60-30/A[3]	344	515	435	403	282	244	433	397	325	313	248	255	315	351	347
1000# Lime/A[4] - No Fertilizer	474	505	502	420	258	171	128	342	190	79	188	243	281	96	277
1000# Lime/A[4] - 30-60-30/A[3]	487	570	542	422	339	275	335	463	316	310	385	313	292	249	378
LSD (.05)	71	NS	54	NS	53	NS	74	55	41	84	100	52	57	45	49
LSD (.01)	97	NS	74	NS	73	NS	100	75	56	114	136	71	NS	62	69

[1] Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, Centennial in 1973-planted in May each year and harvested in September.

[2] Applied broadcast in March the first 11 years, then none thereafter.

[3] The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4] Dolomite applied the first 5 years, then calcite the next 6 years, then none.

Table 7. —Grade of sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Grade of Roots (% No. 1)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment - No Fertilizer	72.0	61.2	67.8	39.0	34.8	48.9	56.3	34.2	37.0	31.2	58.5	40.7	16.3	36.0	45.3
No Amendment - 30-60-30/A[3]	68.2	65.5	73.0	51.8	38.5	45.6	78.0	34.2	37.2	39.2	54.5	54.2	25.3	36.0	50.1
320# S/A - No Fertilizer	62.2	58.2	71.3	35.5	43.2	54.4	78.7	50.2	65.8	48.8	60.3	34.2	20.5	45.1	52.0
320# S/A - 30-60-30/A[3]	69.3	67.3	66.7	58.0	37.2	63.7	78.0	55.8	67.8	43.8	64.2	50.3	17.7	56.2	56.9
1000# Lime/A[4] - No Fertilizer	69.7	64.5	69.7	40.0	25.8	23.5	48.2	9.5	9.5	23.3	38.2	46.5	22.7	35.3	37.6
1000# Lime/A[4] - 30-60-30/A[3]	61.8	71.5	73.3	47.3	25.7	31.3	44.5	16.2	10.0	17.3	30.3	48.2	30.0	34.1	38.7
LSD (.05)	13.7	6.5	NS	10.4	NS	21.7	18.9	12.8	10.8	10.9	14.0	10.8	8.6	13.9	8.9
LSD (.01)	18.7	8.9	NS	14.1	NS	29.3	25.6	17.4	14.7	14.9	19.0	NS	NS	NS	12.5

[1] Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, Centennial in 1973-Planted in May each year and harvested in September.

[2] Applied broadcast in March the first 11 years, then none thereafter.

[3] The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4] Dolomite applied the first 5 years, then calcite the next 6 years, then none.

for the sulfur amendment, but this did not occur with L4-186. A positive response was shown by both seedlings to fertilizer applications, whether used with a soil amendment or not. In the last year of the study with Centennial again being used as the test cultivar, the detrimental effects of limed soil were clearly demonstrated, as were the beneficial effects of fertilizer used.

The grade of raw roots produced in this experiment was definitely influenced by soil amendment treatment (Table 7). During the first few seasons, the differences in grade attributable to amendments were relatively small although sometimes significant, but as the seasons passed these differences grew wider, so that after ten years the limed plots were producing roots of a much lower grade than the sulfur-treated soil or that which had received no amendment. As pointed out before, this influence on grade was brought about primarily by the greater incidence and severity of soil rot in the potatoes grown on the limed soil. The use of fertilizer appeared to have little bearing on the grade of roots, whether it was applied with an amendment or not. The grade of roots produced by the L4-89 and L4-186 seedlings was not adversely affected by the limed soil, presumably because of their resistance to soil rot.

Beginning with the harvested roots in 1967, a study was conducted of the influence of the soil amendment and fertilizer treatments previously described on certain quality aspects of the potatoes. This study was continued until the end of the experimental period in 1973.

The effects of fertilizer use as an average of soil amendment treatments on the quality of the three cultivars of sweet potatoes grown in this experiment are presented in Table 8. Over a 4-year period, the Centennial control plots without fertilizer were the highest in dry matter content. With the cultivar L4-89, the fertilizer treatment produced potatoes with a higher dry matter content. However, no significant difference was found from fertilization of the L4-186 cultivar. Increasing the soil pH produced a highly significant linear decrease in the dry matter content of Centennial and L4-89 (Figure 6). Soil pH had no influence on the dry matter content of L4-186.

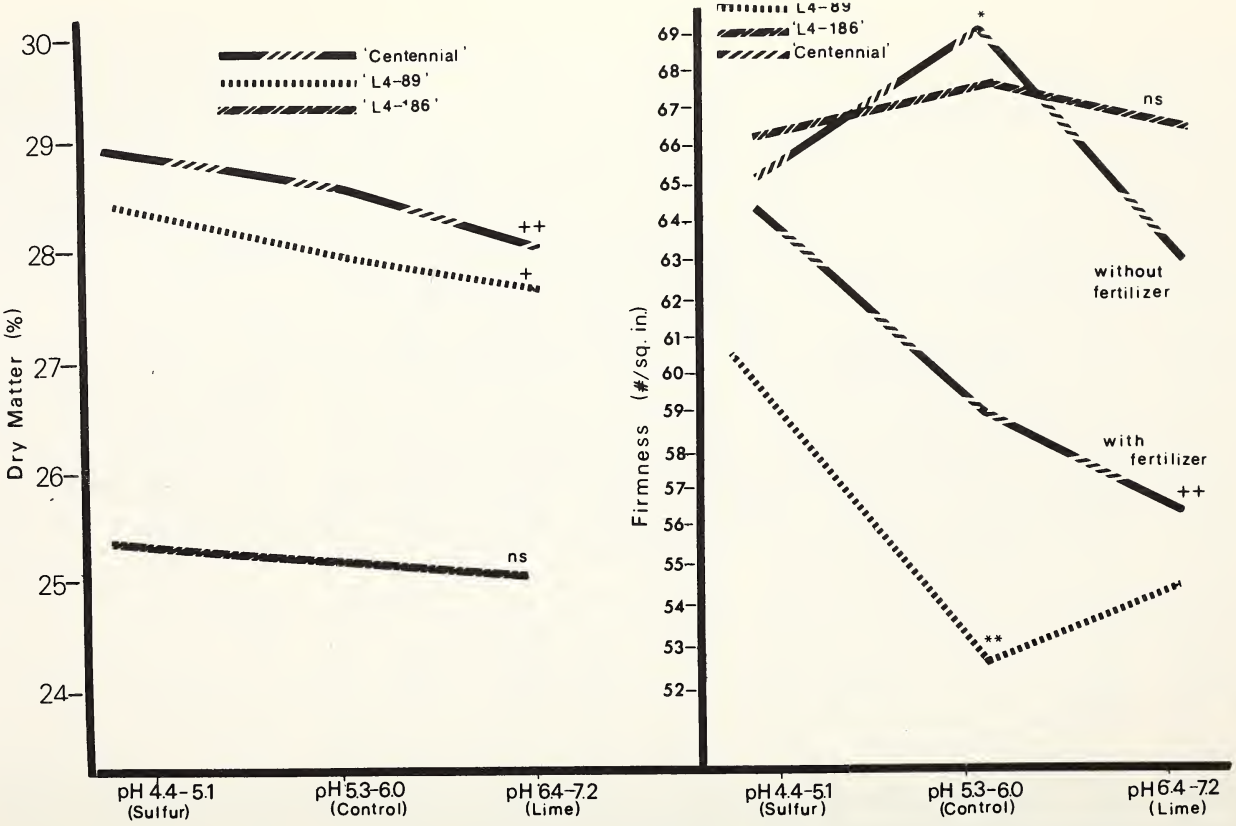
Canned potatoes from plots receiving no fertilizer were significantly firmer in the Centennial cultivar but were softer in L4-186 (Table 8). Firmness of L4-89 was not affected by the addition of fertilizer. A significant interaction occurred between soil pH and fertilizer use with the Centennial cultivar over a 5-year period (Figure 6). Whenever fertilizer was applied, with increasing soil pH there was a highly significant linear decrease in firmness of canned Centennial roots (Figure 6). Without fertilizer, a significant quadratic effect occurred, with the control producing the firmest potatoes. A significant quadratic effect also occurred with L4-89, but the control treatment produced the softest potatoes (1 year's data).

Varying the soil pH by amendment or additions of fertilizer had no

Table 8. — Effects of fertilizer (average of three soil amendment treatments) on quality factors of three cultivars of sweet potatoes

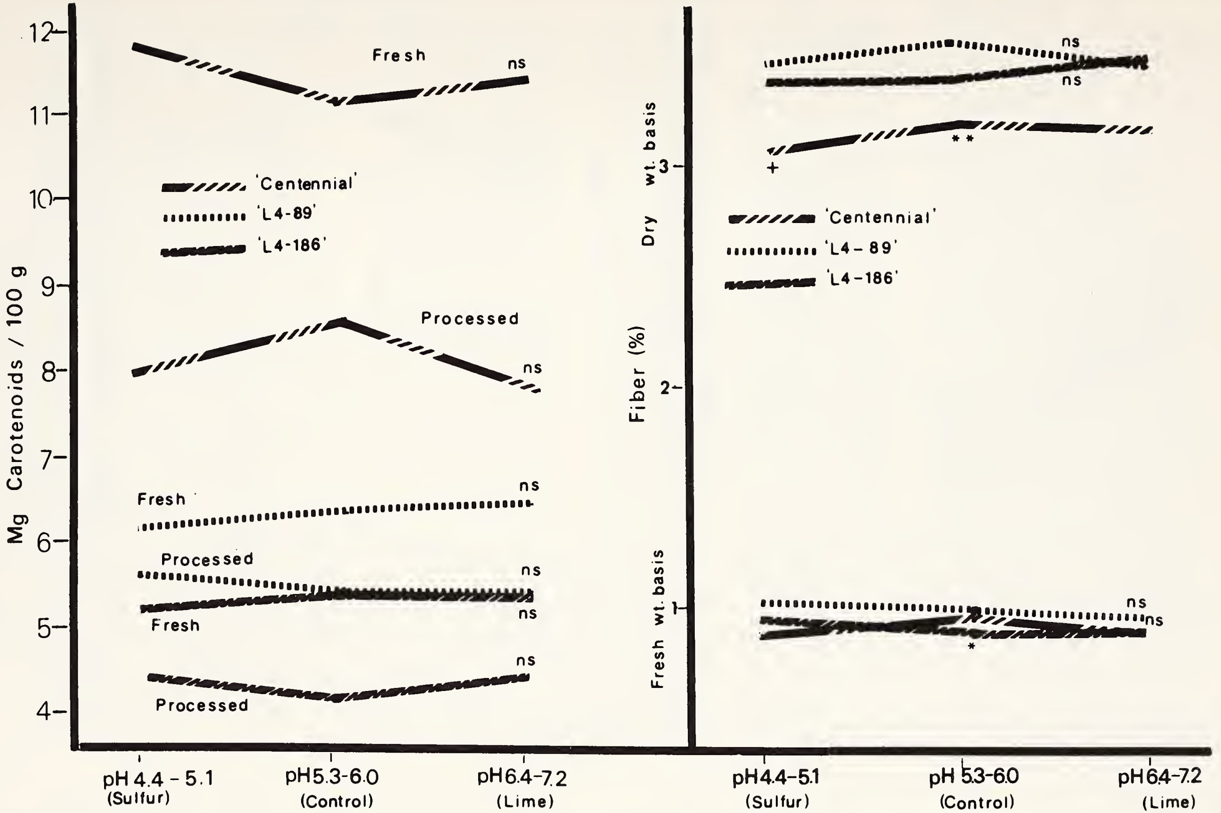
	Percent		Color[y]		Percent fiber		Percent protein		Percent "splits"	
Cultivars	dry matter	Firmness[z]	fresh	canned	dry wt.	fresh wt.	dry wt.	fresh wt.	total	severe
'Centennial'										
0-0-0	28.8**x	65.9**w	11.4 v	8.1	3.17 v	.88*	5.71 v	1.63	45.6 t	23.2
30-60-30	28.0	59.8	11.4	8.1	3.21	.86	6.59**	1.77**	40.0	18.5
			N.S.	N.S.	N.S.					
'L4-186'										
0-0-0	25.0 t	63.4 t	5.1 t	4.1	3.50**t	.87	4.14 t	1.03	21.4 t	9.1
30-60-30	25.5	70.1**	5.5	4.4	3.33	.85	4.96**	1.28**	16.4	4.5
	N.S.		N.S.	N.S.		N.S.			N.S.	N.S.
'L4-89'										
0-0-0	27.6 t	55.5 t	5.3 t	6.3	3.51 t	.97	4.12 t	1.14	--	--
30-60-30	28.4*	56.3	5.4	6.1	3.46	.98	4.78**	1.36**	--	--
		N.S.	N.S.	N.S.	N.S.	N.S.				

[z] Pounds per sq. inch required to shear a 200 gm sample with shear press.
[y] Mg carotenoid pigments/100 gms.
[x] Average of 4 years' data - 1967, 1968, 1970, 1973.
[w] Average of 5 years' data - 1967-1970, 1973.
[v] Average of 3 years' data - 1969, 1970, 1973.
[u] Average of 2 years' data - 1970, 1973.
[t] Average of 1 year's data.
*Significant at the 5% level.
**Significant at the 1% level.
N.S. - Non-significant.



*,** control significantly different at the 5% and 1% levels, respectively. ns - non-significant.
+,++ limed plots significantly different from the sulfur plots at the 5% and 1% levels, respectively.

Figure 6. — Effects of soil amendments (varying soil pH) on dry matter content and firmness of canned sweet potatoes of three cultivars.



*,** control significantly different at the 5% and 1% levels, respectively.
+ sulfur plots significantly lower in fiber than limed plots. (5%)   ns - non-significant.

Figure 7. — Effects of soil amendments (varying soil pH) on carotenoids and fiber content of three sweet potato cultivars.

measurable influence on the flesh color (carotenoid pigments content) of fresh or processed sweet potatoes of any of the three cultivars used (Table 8; Figure 7).

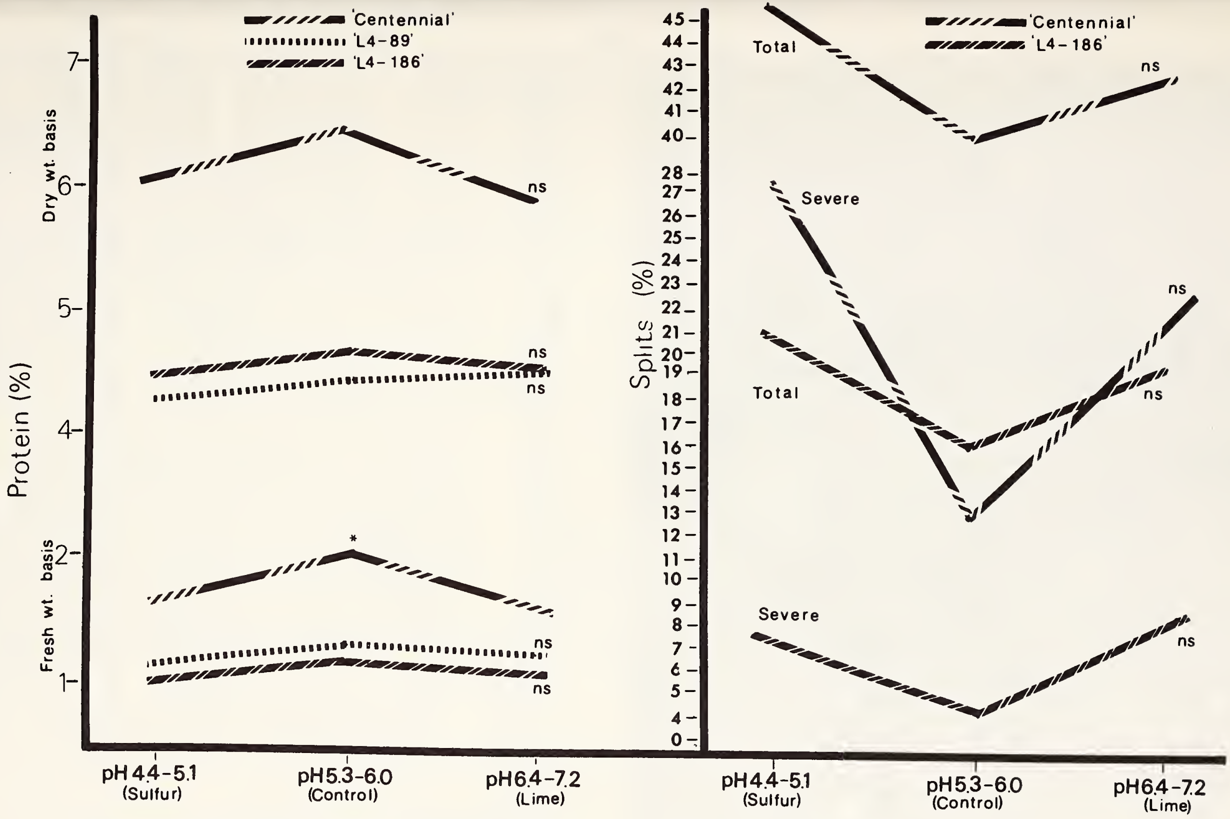
Increasing the soil pH was responsible for a significant linear increase in the fiber content of Centennial sweet potatoes when fiber is expressed as a percentage of the dry matter (Figure 7). This increase in fiber content was rather small. When expressed on a fresh weight basis, a significant quadratic effect occurred, with the control roots (soil pH 5.2) having a higher fiber content. Soil pH had no influence on the fiber content of L4-89 or L4-186 (1 year's results). The addition of fertilizer lowered the fiber content in the Centennial cultivar on a fresh weight basis and in L4-186 on a dry weight basis. However, the use of fertilizer with the cultivar L4-89 had no influence on the fiber content.

Soil pH had some influence on the protein content of one of the three cultivars studied (Figure 8). In the Centennial cultivar, a significant quadratic effect occurred, with the control having the higher protein content (fresh weight basis). The addition of fertilizer did significantly increase the protein content of all three cultivars, both on a fresh and dry weight basis (Table 8).

"Splitting" of the canned roots of Centennial or L4-186 was not influenced by the addition of fertilizer or by variations in soil pH (Table 8; Figure 8). Large variations occurred among replications in "splitting," with the intermediate soil pH level having the lowest percentage of "split" potatoes and "severe splits."

Potatoes from the lime-treated plots had severe soil rot infection, especially on the Centennial cultivar. Soil rot did occur at the intermediate soil pH of 5.3 but not as severely as at pH 6.3. Soil rot lesions greatly reduced the yield of canned potatoes due to the excessive trimming required. Soil rot lesions appeared as black spots on the roots after lye peeling. Sweet potatoes severely infected with soil rot could result in losses during lye peeling and trimming of up to 50 percent.

During the early part of the growing season of 1962, or 3 years after the annual applications of soil amendments and fertilizer had begun, an abnormality appeared on the foliage of the plants growing in the sulfur-treated plots. These symptoms may be described as interveinal chlorosis with some necrosis in severe cases and appeared primarily on the fully mature leaves. Symptoms were less noticeable on the younger expanding leaves and the older leaves near the crown of the plants. A typical plant affected with these symptoms is shown in Figure 9. It may be recalled by reference to Figure 1 that by this time the soil pH in the sulfur-treated plots had dropped to about 4.5. As the growing season of 1962 progressed and the vines extended in length, the severity of the symptoms on the newly-formed leaves was not as striking in appearance as it has been on the younger plants. In fact, by the end of August, practically no symptoms could be found on the foliage that had been formed since the middle part of



* control significantly different at the 5% level. ns - non-significant.

Figure 8. — Effects of soil amendments (varying soil pH) on protein content and splitting of three cultivars of sweet potatoes.

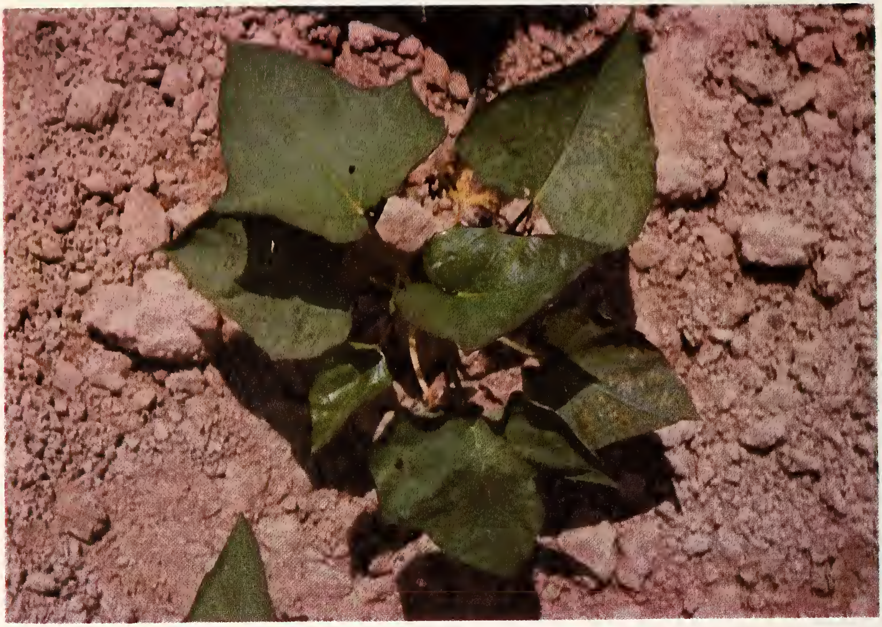


Figure 9. — Effects of the application of sulfur to the soil and the resulting decrease in the soil pH on the presence of chlorotic symptoms on a sweet potato plant growing in the field.

the growing season. Thus, for the rest of the season the foliage of the plants in the sulfur-treated plots appeared perfectly normal and comparable to that which had received no soil amendment treatment (control).

This type of behavior was shown during each subsequent growing season by the plants growing in the sulfur-treated soil. Actually, the symptoms became more pronounced with each passing season; however, they tended to disappear after the early part of the growing season each year. In 1965, it was decided to determine the manganese content of some of the leaves showing marked symptoms of abnormality, since manganese toxicity had been shown to occur in other crops in Louisiana on Mississippi Terrace soils under highly acid conditions. In an effort to avoid any possible influence that fertilizer might have had on the manganese concentration of the foliage, only the unfertilized plots were sampled for analysis, although in the sulfur-treated soil both the fertilized and unfertilized plants were showing pronounced symptoms of a similar degree of severity.

Within a 30-plant plot, one vine from every other hill was selected for the sample. One leaf was taken from this vine at a certain nodal position and combined with another leaf from the same nodal position in the next sampling hill. This procedure was continued until a total of 15 leaves representing a certain nodal position (number from terminal bud) was collected and included in a single sample from each plot. This method of sampling was followed to obtain samples from every other node on the vines growing in the control plot, the sulfur-treated plot, and the limed plot. In using this technique of sampling, it was possible to determine the effect of relative age of leaf as well as soil amendment on the concentration of manganese in the foliage. Along with the foliar samples, a representative sample of the topsoil was taken for pH and extractable manganese determinations. These samples were taken on August 4, 1965, and the results of the analyses of the soil and the leaves are presented in Table 9.

The annual application of amendments had exerted a marked effect on the soil reaction by the 1965 season (Table 9). The use of sulfur had lowered the soil pH to 4.5 while lime applications had raised the value to 6.3. Sulfur applications also greatly increased the extractability of manganese from the soil. On the other hand, lime use only slightly reduced the extractable soil manganese.

The foliar samples from the untreated plots increased in manganese

Table 9. — Soil reaction, extractable soil manganese*, and manganese content of sweet potato leaves** taken from different positions on the vines which had received different soil amendment treatments, 1965

Amendment	Soil pH	Extractable Soil Mn-PPM***	Leaf Position from Terminal Bud	Manganese Content-PPM****
None	5.5	27	Terminal- 2	137
None	5.5	27	- 4	188
None	5.5	27	- 6	275
None	5.5	27	- 8	320
None	5.5	27	-10	362
None	5.5	27	-12	400
None	5.5	27	-14	328
320# Sulfur/A	4.5	165	Terminal- 2	1,325
320# Sulfur/A	4.5	165	- 4	1,825
320# Sulfur/A	4.5	165	- 6	3,000
320# Sulfur/A	4.5	165	- 8	3,025
320# Sulfur/A	4.5	165	-10	2,750
320# Sulfur/A	4.5	165	-10	3,275
320# Sulfur/A	4.5	165	-12	800
1000# Lime/A	6.3	20	Terminal- 2	190
1000# Lime/A	6.3	20	- 4	225
1000# Lime/A	6.3	20	- 6	370
1000# Lime/A	6.3	20	- 8	320
1000# Lime/A	6.3	20	-10	388
1000# Lime/A	6.3	20	-12	425
1000# Lime/A	6.3	20	-14	438
1000# Lime/A	6.3	20	-16	462
1000# Lime/A	6.3	20	-18	250

* Extracted with 1 N ammonium acetate buffered at pH 4.8.

**Sampled on August 4, 1965 along with the soil.

***PPM of the air-dry soil.

****PPM of the oven-dry tissue.

concentration with age of leaf up to the tenth to twelfth node, after which a slight decline in manganese was indicated. These leaves, which appeared completely normal and healthy before analysis, contained from 137 ppm in the youngest leaves to 400 ppm in those 12 nodes from the terminal bud.

The leaves from the sulfur-treated soil were much higher in manganese concentration. Again, the younger leaves were considerably lower than the older ones, with a maximum, 3275 ppm, being reached at the tenth leaf from the terminal bud. Before analysis, these leaves were showing pronounced symptoms of abnormality while the younger leaves with lesser concentrations of manganese, 1395 ppm, were showing milder symptoms. The oldest leaves (node 12) were lowest in manganese concentration (800 ppm). The vines in this plot appeared to be shorter with a smaller number of internodes than the control or limed plot, thus two samples were taken at node number 10.

The leaves from the limed plots were generally similar in manganese concentrations to those from the untreated plots, although more samples were obtained from the longer vines. It is apparent that the manganese concentration increased with age of leaf up to node 16, with a slight decline indicated at node 18. All of the leaves from this plot appeared normal in color and healthy at sampling time as contrasted with those from the sulfur-treated plots which had almost a ten-fold increase in manganese concentration.

In the 1966 season, soil samples and foliar samples were taken from plots representing all combinations of soil amendment and fertilizer applications. In obtaining samples of the foliage, only the tenth leaf from the terminal bud was used to represent a hill, in view of results in the previous year. Other than that, the sampling technique was the same as that used in 1965. These samples were taken on August 3, 1966, and the results of the analyses appear in Table 10.

In the plots where no amendment had been applied, the soil pH had been depressed significantly by the use of fertilizer, although the value was still above 5.0. The sulfur-treated plots were very acid, with little difference in pH due to fertilizer application. On the other hand, in the limed soil the pH approached neutrality when no fertilizer was used, but the application of fertilizer depressed the pH value significantly.

The levels of extractable calcium followed a logical pattern in that they were intermediate in the control plots, relatively low in the sulfur-treated plots, and high in the limed plots. The use of fertilizer had little influence on the extractable calcium level in any plot.

Extractable soil manganese showed a behavior pattern similar to that of the previous year. That is, relatively low levels were extracted from the untreated soil and the limed soil while high levels were obtained from the acid (sulfur-treated) soil. However, the levels from the acid plots were not quite so high as they were in the previous year, 1965. Fertilizer use appeared to have no consistent effect on manganese extractability.

Table 10. — Soil reaction, extractable soil calcium and manganese, and manganese content of sweet potato leaves* taken from plots which had received different soil amendment and fertilizer treatments, 1966

Treatment	Soil ph	Extractable Ca - PPM**	Extractable Mn - PPM**	Leaf Mn Content - PPM***
No Amendment No Fertilizer	5.8	610	15	538
No Amendment 30-60-30/A	5.1	550	22	645
320# Sulfur/A No Fertilizer	4.4	357	79	2667
320# Sulfur/A 30-60-30/A	4.3	413	91	3097
1000# Lime/A No fertilizer	6.8	1070	21	408
1000# Lime/A 30-60-30/A	6.3	947	15	292
LSD (.05)	0.3	150	29	1145
LSD (.01)	0.5	213	41	1629

*Sampled on August 3, 1966 at the tenth node from the terminal bud.

**PPM of air-dry soil.

***PPM of oven-dry tissue.

Leaf manganese concentrations showed wide differences due to amendment applications. Apparently normal and healthy, leaves from the limed plots contained the lowest concentration of manganese, 292 to 408 ppm. In addition, healthy foliage from the untreated soil also had relatively low levels of manganese, 438 to 645 ppm. On the contrary, the chlorotic foliage from the sulfur-treated plots contained much higher concentrations of the element, 2667 to 3097 ppm.

During the following growing season, 1967, additional soil and foliar samples were taken from plots representing all combinations of soil amendment and fertilizer applications. These samples were obtained from the field on August 2, 1967, and were handled in the same manner as those taken in 1966. The analytical results obtained with these samples are shown in Table 11.

The effects of soil amendment and fertilizer on the soil reaction closely paralleled those of the previous year, namely, that the control plots were moderately acid, the sulfur-treated plots were highly acid, and the limed plots approached neutrality, with fertilizer use also exerting a depressing effect on soil pH.

Likewise, as in 1966, the major influence on extractable soil calcium was soil amendment application. More specifically, the untreated soil was intermediate, the sulfur-treated soil was lowest, and the limed soil was highest in extractable calcium content. Fertilizer use had little bearing on this constituent of the soil.

Also, as was true in the previous year, the primary factor affecting the extractability of soil manganese was the application of the sulfur amendment. This treatment greatly increased the level of extractable manganese,

Table 11. — Soil reaction, extractable soil calcium and manganese, and manganese content of sweet potato leaves* taken from plots which had received different soil amendment and fertilizer treatments, 1967

Treatment	Soil pH	Extractable Ca - PPM**	Extractable Mn - PPM**	Leaf Mn Content - PPM***
No Amendment No Fertilizer	5.4	340	24	458
No Amendment 30-60-30/A	5.1	433	24	494
320# Sulfur/A No Fertilizer	4.4	195	56	1598
320# Sulfur/A 30-60-30/A	4.3	190	87	2823
1000# Lime/A No Fertilizer	6.9	765	28	320
1000# Lime/A 30-60-30/A	6.3	740	22	297
LSD (.05)	0.4	102	20	846
LSD (.01)	0.5	139	27	1154

*Sampled on August 2, 1967 at the tenth node from the terminal bud.

**PPM of air-dry soil.

***PPM of oven-dry tissue

while the control plots and the limed soil remained at relatively low levels.

As for leaf manganese in 1967, the chlorotic foliage from the sulfur-treated soil was by far the highest in manganese concentration. Ranking second were the control plots, with foliage from the limed plots falling slightly below the foliage from the untreated soil. No consistent influence of fertilizer use was shown on foliar manganese concentration. The leaves from the control plots and the limed plots appeared perfectly healthy and normal.

In 1968, more elaborate plans were formulated to allow a more thorough investigation into the actual cause of the development of the symptoms of abnormal foliage. Preparations were made and preliminary chemical analyses were conducted on soil samples and foliar samples in accordance with procedures outlined under Materials and Methods.

During the seasons of 1969 and 1970, soil samples were taken from each plot in March, June, and August. The samples in June were taken from each plot at the same time as a foliar sample was taken. The soil was tested in the laboratory for reaction and for extractable calcium, manganese, iron, and aluminum. The results of these analyses appear in Table 12.

The soil reaction in the plots receiving no amendment remained fairly constant at the moderately acid level throughout the sampling period in both seasons. The use of fertilizer appeared to have a slightly depressing effect on the soil pH. The sulfur-treated plots continued to show strong acidity, with some tendency to become more acid with the passage of the season. On the other hand, the limed plots remained near neutrality in reaction during the sampling period of both seasons, with only a slight trend toward acidification as a result of fertilization.

In the control (not amended) plots in 1969, calcium was extractable at

Table 12. — The effect of soil amendments and fertilizer applications on the soil reaction and the level of extractable calcium, manganese, iron, and aluminum in the topsoil of Grenada silt loam sampled on three dates during the growing seasons of 1969 and 1970

Treatment	Growing Season	Time of Sampling														
		March					June					August				
		Soil pH	Ca*	Mn*	Fe*	Al*	Soil pH	Ca*	Mn*	Fe*	Al*	Soil pH	Ca*	Mn*	Fe*	Al*
No Amendment	1969	5.7	618	71	1.2	52	5.5	577	83	1.2	57	5.6	588	82	1.2	47
No Fertilizer	1970	5.8	336	71	1.2	51	5.5	328	70	1.3	55	5.4	393	48	1.2	49
No Amendment	1969	5.6	736	74	1.2	59	5.1	802	151	1.3	56	5.2	704	101	1.5	52
30-60-30/A	1970	5.6	378	74	1.2	56	5.0	411	132	1.4	60	5.3	450	58	1.4	53
320# Sulfur/A	1969	4.6	300	116	5.5	114	4.4	334	161	6.6	119	4.4	230	158	6.8	118
No Fertilizer	1970	4.7	143	127	5.6	117	4.2	135	179	9.1	140	4.3	151	151	8.4	130
320# Sulfur/A	1969	4.4	333	119	6.8	112	4.1	529	188	7.4	120	4.1	372	170	9.2	125
30-60-30/A	1970	4.5	147	121	7.4	122	4.0	124	211	10.8	162	4.1	138	170	10.4	131
1000# Lime/A	1969	7.1	1264	37	0.6	30	7.0	1318	36	0.6	33	7.2	1344	37	0.6	26
No Fertilizer	1970	7.1	767	36	0.6	27	7.0	909	33	0.7	32	7.2	1004	28	0.6	25
1000# Lime/A	1969	7.0	1261	39	0.6	29	6.3	1398	70	0.6	34	6.8	1308	41	0.6	28
30-60-30/A	1970	6.9	740	42	0.7	27	6.7	925	43	0.6	31	7.0	943	27	0.6	26
LSD .05	1969	0.4	102	14	1.9	17	0.3	85	25	3.3	22	0.4	116	18	5.3	20
	1970	0.4	94	13	2.1	22	0.3	103	19	2.4	21	0.3	103	26	2.6	22
LSD .01	1969	0.5	139	20	2.6	23	0.5	115	35	4.5	31	0.5	158	24	7.2	28
	1970	0.5	129	18	2.9	30	0.4	141	26	3.2	29	0.4	141	36	3.4	31

*PPM of the element extractable with 1 N ammonium acetate solution buffered at pH 4.8.

fairly constant levels during the season, at levels which might be expected in this soil at the prevailing pH; however, during the 1970 season the calcium levels were greatly reduced and were measured at about half of that for the 1969 season. The use of fertilizer tended to increase the amount of extractable calcium in the soil in the control plots. The sulfur-treated plots showed greatly reduced levels of extractable calcium on all sampling dates. Again, far less calcium was extracted from these plots in 1970 than in 1969. The limed plots contained several times more extractable calcium than the sulfur-treated plots and roughly twice as much as the control plots. The indication was strong here also that more calcium was extractable in 1969 than in 1970. By way of explanation, one cannot discount the possibility of some variation from one season to another in the degree of precision in the analytical laboratory, whether the variation be in human efficiency or reagent chemical purity or standardization of equipment.

Extractable soil manganese in all samples was markedly affected by soil amendment treatment. Although some variation was shown by samples from the control plots, the major effect on the element was caused by the applications of sulfur. It is clearly shown that the use of this amendment caused marked increases in manganese extractability throughout the season. Conversely, the use of lime reduced the amount of manganese extracted from the soil.

The amount of iron extractable from the soil was also increased several fold by the application of sulfur to the soil. Liming the soil had the opposite effect, in that it reduced extractable iron by about half its original amount.

The extractability of aluminum from the soil was likewise profoundly affected by soil amendment use. Acidifying the soil with sulfur applications markedly increased the levels of extractable aluminum while making the soil more alkaline by the use of lime had the opposite effect.

The relationships between the soil reaction and the levels of extractable calcium, manganese, iron, and aluminum expressed in terms of simple correlation coefficients are presented in Table 13. It is shown that the soil pH and calcium levels were closely related in a positive manner. On the other hand, extractable soil manganese was definitely related to soil reaction in a negative way, as were soil iron and aluminum. The simplest inference from this table is that as the soil became more acid, less calcium but more manganese, iron, and aluminum were extractable from it. The probability of this inference is high, in view of the large r values.

During the growing seasons of 1969 and 1970, samples of the leaves were taken in June from each plot. Representative samples were obtained from both the sixth nodal position from the terminal bud and the tenth nodal position. The samples were classified with respect to severity of symptoms (chlorosis primarily) and then were analyzed in the laboratory for calcium, manganese, iron, and aluminum contents. The resulting information, along with the pH data on soil samples taken from these plots at the same time, are presented in Table 14.

Table 13. — The relationship between the soil reaction and the levels of extractable* calcium, manganese, iron, and aluminum determined in March, June, and August of 1969 and 1970

Sampling Date	Soil Variables	r Value 1969	r Value 1970	r Value Both Years
March	Soil pH with Extractable Soil Calcium	0.96	0.97	0.95
	Soil pH with Extractable Soil Manganese	-0.94	-0.91	-0.92
	Soil pH with Extractable Soil Iron	-0.79	-0.80	-0.80
	Soil pH with Extractable Soil Aluminum	-0.89	-0.92	-0.90
June	Soil pH with Extractable Soil Calcium	0.87	0.96	0.94
	Soil pH with Extractable Soil Manganese	-0.88	-0.94	-0.91
	Soil pH with Extractable Soil Iron	-0.78	-0.79	-0.76
	Soil pH with Extractable Soil Aluminum	-0.86	-0.87	-0.87
August	Soil pH with Extractable Soil Calcium	0.94	0.97	0.96
	Soil pH with Extractable Soil Manganese	-0.94	-0.86	-0.92
	Soil pH with Extractable Soil Iron	-0.76	-0.79	-0.77
	Soil pH with Extractable Soil Aluminum	-0.87	-0.89	-0.92
r value required for significance at .05 level		0.32	0.32	0.23
r value required for significance at .01 level		0.42	0.42	0.30

*Extracted with 1 N ammonium acetate buffered at pH 4.8.

In the younger (sixth) leaves, the calcium level varied widely with season. Among treatment samples, calcium accumulation was depressed by the sulfur amendment and promoted by lime use. The application of fertilizer reduced the concentration of calcium in the leaves from all plots. The manganese concentration in the leaves from the control (unamended) plots varied somewhat, both with season and with fertilizer application. It may be noted that the highest manganese concentration in the control samples, 2023 ppm, was associated with a soil pH of 5.1 and a chlorosis severity rating of 2.00, while the lowest concentration of manganese, 218 ppm, was related to a soil pH of 5.5 and a chlorosis value of 1.47. The samples from the sulfur-treated soil were much higher in manganese, with some variation indicated due to fertilization. The range of manganese in these samples was 4353 to 6206 ppm, with a soil pH range of 4.0 to 4.4. These leaves were very chlorotic before analysis, as shown by the high severity values ranging from 3.00 to 5.30. The leaves from the limed soil were relatively low in manganese concentration (201 to 694 ppm), the value apparently related to soil pH and fertilizer application. Before analysis, these leaves were completely free of the chlorosis that was so pronounced on the samples from the sulfur-treated soil and also somewhat noticeable on the control samples. The iron concentration of the foliage appeared to be largely unaffected by soil amendment or fertilizer application; however, the leaves did show a tendency to accumulate more iron

Table 14. — The effect of soil amendments and fertilizer applications on the soil reaction and the concentrations of calcium, manganese, iron, and aluminum in sweet potato leaves and on the severity of symptoms appearing on the leaves sampled in June of 1969 and 1970

			Area Sampled									
			Sixth Leaf from Terminal Bud					Tenth Leaf from Terminal Bud				
Treatment	Growing Season	Soil pH	Ca*	Mn*	Fe*	Al*	Severity**	Ca*	Mn*	Fe*	Al*	Severity**
No Amendment	1969	5.5	8516	421	151	528	1.40	--	--	--	--	--
No Fertilizer	1970	5.5	3933	218	122	432	1.47	11367	548	185	768	1.02
No Amendment	1969	5.1	7200	2023	115	384	2.00	17083	4105	179	505	3.40
30-60-30/A	1970	5.0	795	735	87	371	1.09	12833	2850	115	440	1.78
320# Sulfur/A	1969	4.4	4656	4353	143	650	3.80	--	--	--	--	--
No Fertilizer	1970	4.2	1260	4358	62	881	3.00	7160	5900	233	1216	3.84
320# Sulfur/A	1969	4.1	3912	6206	165	817	5.30	7858	8470	229	1204	5.30
30-60-30/A	1970	4.0	1238	5194	139	997	4.52	7433	6383	255	1358	5.17
1000# Lime/A	1969	7.0	11333	294	209	824	1.00	--	--	--	--	--
No Fertilizer	1970	7.0	8508	201	186	646	1.00	15400	342	245	1030	1.00
1000# Lime/A	1969	6.3	7983	694	121	422	1.00	22183	1149	142	463	1.00
30-60-30/A	1970	6.7	2298	262	96	336	1.00	13100	731	110	360	1.00
LSD (.05)	1969	0.3	1240	1162	33	184	1.10	5853	1060	60	147	0.96
	1970	0.3	3185	1316	60	313	0.75	2718	1241	78	420	0.80
LSD (.01)	1969	0.5	1692	1582	45	251	1.15	8225	1508	86	209	1.36
	1970	0.4	4344	1795	82	438	1.22	3707	1692	107	573	1.15

*PPM of the element on a dry weight basis.

**Based on a scale of 1 for no symptoms to 9 for very severe symptoms.

from all plots in 1969 than in 1970. The aluminum concentration did not appear in a regular pattern among treatment effects. That is, while acidification of the soil by sulfur applications increased the aluminum in the leaves, a similar response was noted from neutralizing the soil acidity with lime in the plots where no fertilizer was applied. Furthermore, the effect of fertilizer use on foliar aluminum was inconsistent, sometimes increasing it and at other times decreasing it. An interesting point is that some of the leaves that were among the highest in aluminum concentration showed no sign of chlorosis whatsoever.

In the older (tenth) leaves, the calcium level was considerably higher in all samples than it was in the younger ones (sixth), as shown in Table 14. In 1969, the unfertilized plots had not produced ten nodes of growth by June, so no data was obtained for them. In the control (unamended) plot, the use of fertilizer did not appear to affect the concentration of calcium in the foliage. The outstanding effect of the amendments was the repression of foliar calcium in the samples from the sulfur-treated soil. Conversely, foliar calcium concentrations were highest in the leaves from the limed plots, with only relatively small influences of fertilizer use being shown. As for foliar manganese, the control plot samples which varied in severity of symptoms from slight to moderate contained widely different amounts of manganese (548 ppm from plots with a pH of 5.5 to 4105 ppm from plots with a pH of 5.1). However, by far the highest concentration of foliar manganese (5900 to 8470 ppm) was found in the samples from the sulfur-treated soil (pH 4.0 to 4.4). These leaves were very chlorotic before analysis, ranging in severity from 3.84 to 5.30. Leaves collected from the limed plots were much lower in manganese (342 to 1149 ppm) and showed no chlorotic symptoms whatsoever. As for foliar iron concentration, the differences, although sometimes significant, did not follow any regular pattern of influence by soil amendment or fertilizer application. The aluminum concentration of the leaves varied inconsistently with soil amendment application and pH. The samples highest in aluminum (1358 ppm) were obtained from the sulfur-treated plots (pH 4.0); however, the samples which were intermediate in aluminum (1030 ppm) came from the limed soil (pH 7.0). These leaves were entirely free of chlorotic symptoms while some of those from the control (unamended) plot which contained only 505 ppm of aluminum were moderately chlorotic.

Some of the relationships indicated by the data in Table 14 between the severity of the chlorotic symptoms on the foliage, the soil pH, the levels of extractable calcium, manganese, iron, and aluminum from the soil, and the concentrations of these elements in the leaves are better understood when expressed in terms of correlation coefficients as in Table 15. It is clear from the consistently high negative r value that the chlorosis in the foliage became more severe as the soil pH was reduced. This negative association was also shown between the extractable soil calcium and the degree of

Table 15. — The relationship between the severity of symptoms on the sixth and tenth leaves* from the terminal bud and the soil* pH, the levels of extractable calcium, manganese, iron, and aluminum from the soil, and the concentrations of these elements in the leaves in 1969 and 1970

Variables	r Value			
	Sixth Leaf		Tenth Leaf	
	1969	1970	1969	1970
Severity with Soil pH	-0.79	-0.74	-0.79	-0.79
Severity with Extractable Soil Calcium	-0.74	-0.77	-0.44	-0.70
Severity with Extractable Soil Manganese	0.79	0.82	0.44	0.87
Severity with Extractable Soil Iron	0.86	0.94	0.36	0.88
Severity with Extractable Soil Aluminum	0.83	0.87	0.12	0.88
Severity with Leaf Calcium	-0.75	-0.27	-0.35	-0.75
Severity with Leaf Manganese	0.94	0.98	0.66	0.87
Severity with Leaf Iron	0.07	0.29	0.36	0.33
Severity with Leaf Aluminum	0.46	0.73	0.39	0.49
r value required for significance at .05 level	0.32	0.32	0.46	0.32
r value required for significance at .01 level	0.42	0.42	0.59	0.42

*Sampled in June, 1969 and 1970.

chlorosis of the foliage. Equally definite was the positive association between extractable soil manganese and severity of chlorosis, illustrating that the soil that released the most manganese to the extractant also produced sweet potato foliage that was the most chlorotic. The severity of chlorosis was also positively related to extractable soil iron and aluminum. In regard to foliar levels of these elements, leaf calcium was negatively related to severity of chlorosis; however, leaf manganese was consistently positively associated with chlorosis, meaning that the higher the concentration of leaf manganese the greater the degree of chlorosis of the foliage. Leaf iron showed some tendency toward positive relation with severity of symptoms, but the r value was much lower than that for leaf manganese. This was also true for leaf aluminum.

Other relationships such as that between the soil reaction and the concentrations of calcium, manganese, iron, and aluminum in the leaves, as well as that between the levels of extractable soil calcium, manganese, iron, and aluminum, and the concentrations of these elements in the leaves are presented as correlation values in Table 16.

It is clear from the r values presented that the soil pH was positively related to the calcium concentration of the leaves; however, the opposite was true with respect to leaf manganese and soil pH, a good indication that as the soil became more acid more manganese was accumulated in the leaves. The soil reaction did not have a consistent influence on the iron concentration in the leaves, and the aluminum concentration in the foliage, although negatively related to soil pH, did not show as close an association with it as did foliar manganese. The r values indicate that extractability of both calcium and manganese from the soil is a good index of what the concentration of these elements may be in the foliage. These indications are also shown for soil iron with leaf iron and soil aluminum with leaf

Table 16. — The relationship between the soil* pH and the concentrations of calcium, manganese, iron, and aluminum in the sixth and tenth leaves* from the terminal bud, and the relationship between the extractable levels of these elements in the soil and their concentrations in the leaves in 1969 and 1970

Variables	r Values			
	Sixth Leaf		Tenth Leaf	
	1969	1970	1969	1970
Soil pH with Leaf Calcium	0.88	0.56	0.74	0.79
Soil pH with Leaf Manganese	-0.82	-0.77	-0.91	-0.81
Soil pH with Leaf Iron	0.26	0.03	-0.68	-0.19
Soil pH with Leaf Aluminum	-0.06	-0.46	-0.81	-0.37
Extractable Soil Calcium with Leaf Calcium	0.69	0.45	0.81	0.77
Extractable Soil Manganese with Leaf Manganese	0.83	0.85	0.87	0.83
Extractable Soil Iron with Leaf Iron	0.15	0.32	0.65	0.43
Extractable Soil Aluminum with Leaf Aluminum	0.43	0.70	0.43	0.58
r value required for significance at .05 level	0.32	0.32	0.46	0.32
r value required for significance at .01 level	0.42	0.42	0.59	0.42

*Sampled in June, 1969 and 1970.

aluminum, but the probability values substantiating these relationships are much lower than those for calcium and manganese, meaning that extractability of iron and aluminum from the soil is not as good an index of accumulation of these elements by the foliage as is that for calcium and manganese.

During the seasons of 1969 and 1970, additional foliar samples were taken from each treatment plot in August. Representative samples were obtained from each of the sixth, tenth, and fourteenth nodal positions. Each sample was rated for severity of chlorosis and then analyzed for calcium, manganese, iron, and aluminum contents. The information gained, along with soil pH data on samples taken at the same time, is shown in Table 17.

The youngest leaves (sixth node) showed wide variation in calcium level between seasons in all plots. Among treatment samples, the concentration of calcium was reduced by sulfur applications and unaffected by lime use. This lack of response to lime application does not coincide with the results obtained with the samples taken in June. The use of fertilizer tended to reduce the calcium level in all samples. The manganese level in these leaves was also affected by season as well as amendment. In all cases, manganese was higher in 1969. The greatest response in foliar manganese was to sulfur applications where the levels were sharply increased; however, the levels in these samples were much lower than that in the corresponding samples taken in June (Table 14). It is noteworthy also that these samples, even with as much as 1292 ppm of manganese, showed no signs of chlorosis. The use of lime tended to reduce manganese in the foliage. Neither soil amendment nor fertilizer application appeared to have any influence on the iron level in the leaves, and the aluminum concentration showed only small irregular variations with treatment. Again, it should be noted that none of these leaves displayed any signs of chlorosis.

Table 17. — The effect of soil amendments and fertilizer applications on the soil reaction and the concentration of calcium, manganese, iron, and aluminum in sweet potato leaves and on the severity of symptoms appearing on leaves sampled in August of 1969 and 1970

Treatment	Growing Season	Soil pH	Area Sampled														
			Sixth Leaf from Terminal Bud					Tenth Leaf from Terminal Bud					Fourteenth Leaf from Terminal Bud				
			Ca*	Mn*	Fe*	Al*	Severity**	Ca*	Mn*	Fe*	Al*	Severity**	Ca*	Mn*	Fe*	Al*	Severity**
No Amendment	1969	5.6	1552	273	128	369	1.00	4182	431	150	461	1.00	6683	556	218	704	1.00
No Fertilizer	1970	5.4	282	75	129	423	1.00	1217	296	125	501	1.02	3817	492	165	624	1.01
No Amendment	1969	5.2	1282	268	78	253	1.00	3322	470	102	320	1.02	8150	780	144	489	1.00
30-60-30/A	1970	5.3	310	92	74	293	1.00	1150	340	65	276	1.07	2317	545	95	355	1.00
320# Sulfur/A	1969	4.4	919	881	87	301	1.00	2218	1589	176	563	1.02	4223	2418	237	775	1.09
No Fertilizer	1970	4.3	325	511	123	438	1.00	933	1564	137	571	1.09	1958	2430	188	713	1.02
320# Sulfur/A	1969	4.1	810	1292	78	348	1.00	2128	2871	121	339	1.15	5007	3917	178	522	1.27
30-60-30/A	1970	4.1	392	710	91	353	1.00	1008	2135	115	424	1.27	2483	3498	137	494	1.68
1000# Lime/A	1969	7.2	1567	167	79	251	1.00	7417	278	94	295	1.00	14950	379	162	487	1.00
No Fertilizer	1970	7.2	403	68	97	348	1.00	2117	209	111	413	1.00	7117	297	134	514	1.00
1000# Lime/A	1969	6.8	1102	167	81	231	1.00	5058	249	83	252	1.00	11150	381	112	336	1.00
30-60-30/A	1970	7.0	322	41	65	253	1.00	1392	201	66	243	1.00	5042	286	82	277	1.00
LSD (.05)	1969	0.4	471	349	31	113	NS	2101	752	37	124	NS	2182	1075	42	154	NS
	1970	0.3	NS	295	36	NS	NS	353	842	38	148	NS	1654	1123	46	154	NS
LSD (.01)	1969	0.5	643	476	42	154	--	2898	1025	51	169	--	2976	1466	58	210	--
	1970	0.4	NS	403	49	NS	--	481	1148	52	201	--	2256	1532	63	210	--

*PPM of the element on a dry weight basis.

**Based on a scale of 1 for no symptoms to 9 for very severe symptoms.

The medium-age leaves (tenth node) were much higher in calcium than the younger ones (sixth node), with the concentrations in all samples in 1969 considerably above those in 1970 (Table 17). Again, the depressing effect of sulfur applications to the soil on foliar calcium levels was shown, as was the stimulating influence of lime applications. Fertilization was inconsistent in its effect on foliar calcium. The manganese levels were lower in the younger leaves. Some of the leaves in the control plots were showing traces of chlorosis, although the manganese concentrations were well below those which had previously been associated with foliar chlorosis. Again, the soil which had been acidified by use of sulfur produced leaves much higher in manganese concentration than the other leaves. Fertilization also appeared to increase foliar manganese levels. The leaves from the sulfur-treated plots, with 1564 to 2871 ppm of manganese, were showing a mild degree of chlorosis while those from the limed soil were not showing any discoloration. The samples from the limed plots, at 201 to 278 ppm, were also far below those from the highly acid soil in manganese concentration. The accumulation of iron by the leaves appeared to be independent of soil or fertilizer use. Similarly, no clear-cut pattern of aluminum accumulation was shown, although some of the samples from the highly acid soil appeared to be higher in aluminum than others.

The oldest leaves (fourteenth node) were even higher in calcium concentration than the middle-aged ones (Table 17). The effect of season was still present in that leaves in 1969 accumulated more calcium than those in 1970. The depressing effect of sulfur applications and the stimulating influence of lime use on foliar calcium were still evident in leaves of this age. A fertilization influence on foliar calcium accumulation was inconsistent. The manganese levels were generally higher in these leaves than they were in the middle-aged or youngest leaves. Practically no chlorotic symptoms could be found on the leaves from the control (unamended) plots which varied in manganese concentration from 492 to 780 ppm. However, the leaves from the sulfur-treated soil (pH 4.1 to 4.4) contained from 2418 to 3917 ppm of manganese and were showing mild symptoms of chlorosis in most cases. The limed soil (pH 6.8 to 7.2) produced leaves with 297 to 318 ppm of manganese and had no sign of chlorosis. The foliar iron concentration again showed no response to either soil amendment or fertilizer application. The pattern for foliar aluminum was so varied that it was difficult to assign a definite response to either soil amendment or fertilizer application.

Some of the relationships shown in tabular form in Table 17 between treatment factors and effects are summarized in Table 18 in correlation form as r values. With one exception, sixth leaf-1970, the results point to a fairly close relationship between soil pH and leaf calcium level. This inference is in agreement with the results obtained with the samples taken

Table 18. — The relationship between the soil* pH and the concentrations of calcium, manganese, iron, and aluminum in the sixth, tenth, and fourteenth leaves* from the terminal bud, and the relationship between the extractable levels of these elements in the soil and their concentrations in the leaves in 1969 and 1970

Variables	r Value					
	Sixth Leaf		Tenth Leaf		Fourteenth Leaf	
	1969	1970	1969	1970	1969	1970
Soil pH with Leaf Calcium	0.46	0.03	0.77	0.72	0.88	0.64
Soil pH with Leaf Manganese	-0.71	-0.65	-0.71	-0.64	-0.74	-0.73
Soil pH with Leaf Iron	-0.04	-0.29	-0.50	-0.36	-0.46	-0.39
Soil pH with Leaf Aluminum	-0.29	-0.26	-0.45	-0.38	-0.47	-0.38
Extractable Soil Calcium with Leaf Calcium	0.34	0.09	0.74	0.74	0.90	0.68
Extractable Soil Manganese with Leaf Manganese	0.73	0.81	0.77	0.76	0.80	0.89
Extractable Soil Iron with Leaf Iron	-0.11	0.28	0.39	0.46	0.39	0.45
Extractable Soil Aluminum with Leaf Aluminum	0.31	0.38	0.54	0.51	0.54	0.50
r value required for significance at .05 level	0.32	0.32	0.32	0.32	0.32	0.32
r value required for significance at .01 level	0.42	0.42	0.42	0.42	0.42	0.42

*Sampled in August,1969 and 1970.

in June. Furthermore, as was true with the June sample, a highly negative association was shown between soil pH and foliar manganese level, meaning that the more acid soil resulted in increased accumulation of manganese by the leaves. Again, as in June, neither leaf iron nor leaf aluminum showed a very high dependence on soil pH, although the r value was consistently negative. The extractability of calcium, and especially manganese, from the soil had a major influence on the concentration of these elements in the leaves. This relationship was also found with the samples taken in June. The amount of extractable iron in the soil showed some relationship to foliar iron, and aluminum extractability was generally related to foliar aluminum concentration.

The disease data shown in Tables 19 and 20 show highly significant effects due to amendments and thereby confirm the effectiveness of sulfur application to the soil for controlling soil rot and the importance of soil pH in determining soil rot severity as previously reported (*26*, *34*, *35*). These data also show highly significant differences in disease severity from year to year with the lowest severity index of 18.5 in 1967 and the highest of 29.8 in 1966. Such variability in soil rot severity during different growing seasons was reported earlier (*34*). There was a significant interaction indicated between amendment and fertilizer with soil rot severity greater in the limed plots receiving no fertilizer than in those fertilized, while soil rot severity was lower in the unfertilized than in the fertilized plots receiving sulfur or no amendment. There also was a significant interaction indicated between years and amendments. This appears to be due to the increase of soil rot severity in the sulfur-treated plots and the decrease in severity index in the limed plots in 1973, two years after addition of amendments ceased, as well as to the gradual increase in severity in plots receiving no amendments.

The results in Table 21 show the effects of the treatments on vine growth.

Table 19. —Percentage[1] soil-rot-affected Centennial sweet potatoes grown on Grenada silt loam soil with different soil amendments and fertilizer applications at Chase, La., 1965-70 and 1973

	Years and Percentages							
Amendment-Fertilizer	1965	1966	1967	1968	1969	1970	1973	Average
none - none	20.3	29.7	30.0	36.3	47.7	42.3	43.2	35.6
none - 30-60-30/A	23.3	12.2	35.0	53.5	48.3	52.2	53.8	39.8
320# S/A - none	5.8	6.2	11.0	4.5	13.8	9.5	17.7	9.8
320# S/A - 30-60-30/A	6.0	3.0	10.5	4.3	24.8	13.3	22.7	12.1
1000# Lime/A - none	72.7	90.3	82.7	91.3	90.0	76.2	70.8	82.0
1000# Lime/A - 30-60-30/A	63.0	60.8	77.2	86.7	77.5	86.7	62.3	73.5
Average	31.9	33.7	41.1	46.1	50.4	46.7	45.1	42.1

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[1] Averages of 6 replications.

A summary of the statistical analysis of the combined data for the seven years is given. Amendments and fertilizer were considered fixed effects and years as random effects in the analysis. Mean square for Error D was 361.9. * and ** denote significance at the 5% and 1% level of probability, respectively.

Analysis Summary:

Source of Variation	Degrees of Freedom	Error Term Used	F-values
Total	251		
Columns/years	35	D	0.57
Rows/years	35	D	1.21
Years	6	D	4.82**
Amendments	2	A	130.68**
Fertilizer	1	B	0.06
Amend. x Fert.	2	C	6.58*
Years x Amend. (Error A)	12	D	2.01*
Years x Fert. (Error B)	6	D	1.53
Years x Amend. x Fert. (Error C)	12	D	0.41
Remainder (Error D)	140		

Table 20. — Soil rot severity indexes[1] on Centennial sweet potatoes grown on Grenada silt loam soil with different soil amendments and fertilizer applications at Chase, La., 1965-70 and 1973

	Years and Percentages							
Amendment-Fertilizer	1965	1966	1967	1968	1969	1970	1973	Average
none - none	10.2	15.2	11.2	20.0	21.5	19.0	23.0	17.1
none - 30-60-30/A	13.3	6.0	13.0	28.2	19.8	24.8	33.0	19.7
320# S/A - none	2.0	2.7	3.7	2.2	4.3	3.0	9.3	3.9
320# S/A - 30-60-30/A	2.0	1.3	3.5	1.5	7.2	4.0	11.7	4.5
1000# Lime/A - none	57.3	55.7	43.8	65.5	51.2	38.5	42.2	50.6
1000# Lime/A - 30-60-30/A	41.8	32.3	36.0	61.2	35.8	50.8	40.7	42.7
Average	21.1	18.9	18.5	29.8	23.3	23.4	26.6	23.1

[1] Averages of 6 replications.

A summary of the statistical analysis of the combined data for the 7 years is given. Amendments and fertilizer were considered fixed effects and years as random effects in the analysis. Mean square for error D was 197.88. * and ** denote significance at the 5% and 1% levels of probability, respectively.

Analysis Summary:

Source of Variation	Degrees of Freedom	Error Term Used	F-values
Total	251		
Columns/years	35	D	0.47
Rows/years	35	D	0.73
Years	6	D	3.02**
Amendments	2	A	91.89**
Fertilizer	1	B	0.51
Amend. x Fert.	2	C	5.70*
Years x Amend. (Error A)	12	D	2.16*
Years x Fert. (Error B)	6	D	1.58
Years x Amend. x Fert. (Error C)	12	D	0.58
Remainder (Error D)	140		

The soil rot fungus causes rotting of the small feeder roots resulting in stunting of the plants (*34, 35*). Therefore, severity of soil rot is indicated by vigor and amount of vine growth. The data in Table 21 show highly significant effects due to years as expected because of the soil moisture relationships to soil rot (*34, 35*). There also was a significant effect on vine growth due to fertilizer with the best vine growth generally shown in the fertilized plots. There was a highly significant interaction indicated between years and amendment, which was related more to injury caused by low pH in the sulfur plots in 1970 than to disease, although there was evidence of greater disease severity in 1970 in the plots receiving no amendment, resulting in considerably poorer vine growth in those plots. There was also a highly significant interaction indicated between years, amendments, and fertilizers (Table 21).

There was a highly significant positive correlation for the 7 years' data between average disease severity indexes in each of the six treatments and average soil pH values in each of the six treatment plots. The correlation coefficient for this comparison was 0.935.

The results from the disease data obtained in this experiment confirm the effectiveness of sulfur application to the soil in controlling soil rot, but emphasize the pitfalls of using this practice unless very carefully controlled applications are made based on adequate soil tests over the entire field under consideration. The data also show that adding lime to soils with pH of 5.2 will greatly enhance soil rot development when the causal fungus is present.

Table 21. — Vine growth ratings[1] on Centennial sweet potatoes grown on Grenada silt loam soil with different soil amendments and fertilizer applications at Chase, La., 1965, 1966, and 1970

	Year and Vine Growth Rating			
Amendment-Fertilizer	1965	1966	1970	Average
none - none	3.0	3.5	1.8	2.77
none - 30-60-30/A	4.0	3.8	4.0	3.93
320# S/A - none	2.8	3.2	2.3	2.77
320# S/A - 30-60-30/A	3.2	3.5	2.2	2.97
1000# Lime/A - none	2.0	1.3	1.5	1.60
1000# Lime/A - 30-60-30/A	3.3	3.3	3.3	3.30
Average	3.08	3.10	2.52	2.90

[1] Averages of 6 replications. Each plot was rated into one of 4 classes: 1 = poor; 2 = fair; 3 = good; 4 = very good vine growth 7 to 9 weeks after planting.

A summary of the statistical analysis of the combined data for the 3 years is given. Amendments and fertilizer were considered as fixed effects and years as random effects in the analysis. Mean square for error D was 0.2585. * and ** denote significance at the 5% and 1% levels of probability, respectively.

Analysis Summary:

Source of Variation	Degrees of Freedom	Error Term Used	F-values
Total	107		
Columns/years	15	D	1.61
Rows/years	15	D	1.27
Years	2	D	14.43**
Amendments	2	A	6.53
Fertilizer	1	B	83.56**
Amendments x fertilizer	2	C	5.51
Years x amendment (Error A)	4	D	4.24**
Years x fertilizer (Error B)	2	D	1.39
Years x Amend. x Fert. (Error C)	4	D	4.06**
Remainder (Error D)	60		

Summary

The effect of changing the natural reaction of a Mississippi River Terrace soil (Grenada silt loam) on sweet potato growth, production, and quality was studied. The pH changes were interacted with fertilizer effects and were brought about by annual applications of sulfur and lime prior to fertilization.

As the sulfur-treated plots became more acid, plant growth was somewhat restricted, especially during the early part of the growing season. A definite pattern of chlorosis appeared on the foliage which was closely related to an abnormally high accumulation of manganese in the leaves. Other elements, such as aluminum and calcium, appeared to be less involved in causing the abnormality of the foliage. The amounts of manganese which could be easily extracted from the soil also increased markedly with decreases in the soil pH. Yields were decreased somewhat in the acidified soil.

As the limed plots became more alkaline, vine growth was reduced to some extent, especially in the unfertilized plots. Also, the yield of marketable potatoes was greatly reduced due to the incidence and severity of soil rot infection in the roots which was increased in proportion to the increase in soil pH. This type of response was also found in the potatoes from the sulfur-treated plots where soil rot infection was greatly reduced by the highly-acid soil.

Only minor differences were found in the dry matter or carotene content of the roots as a result of having been grown in the sulfur-treated or limed soil. Likewise, canning quality was not materially affected by soil amendment or fertilizer application.

The information presented herein illustrates the danger of growing sweet potatoes on Mississippi River Terrace soils that have become highly acid in reaction. This practice would probably result in the plants accumulating an excessive amount of manganese in the tissue, and depressed vine growth and corresponding reductions in yield may be noted.

Additional information presented in this bulletin points out the hazard of growing soil rot susceptible sweet potatoes on these soils that have been limed, providing conditions suitable for the development of the soil rot organism. In this case, the yield of marketable roots will probably be greatly reduced.

Therefore, because of the two undesirable prospects facing him in terms of improper soil reaction, the grower of soil rot susceptible sweet potatoes should maintain his soil pH in the moderately acid range for good production of high quality roots.

Literature Cited

1. Adams, F. and J. E. Wear. 1957. Manganese Toxicity and Soil Acidity in Relation to Crinkle Leaf in Cotton. Soil Sci. Soc. Amer. Proc. 21: 305-308.
2. Anderson, C. A. et al. 1968. Methods of Analysis. Univ. of Fla. Citrus Expt. Sta., Lake Alfred.
3. Association of Official Analytical Chemists. 1970. Method of Analysis. 11th ed. Assoc. Off. Anal. Chem., Washington, D. C.
4. Balerdi, F. F. 1971. The Response by Sweet Potatoes to Various Calcium Salts Applied to Providence Silt Loam and Stough Very Fine Sandy Loam Soils. Ph. D. Dissertation. La. State University.
5. Berger, K. C. and G. C. Gerloff. 1947. Manganese Toxicity of Potato in Relation to Strong Soil Acidity. Soil Sci. Soc. Amer. Proc. 12:310-314.
6. Bortner, C. W. 1935. Toxicity of Manganese to Turkish Tobacco in Acid Kentucky Soils. Soil Sci. 39:15-34.
7. Brupbacher, R. H., J. E. Sedberry, Jr., W. P. Bonner, W. J. Peevy, and W. H. Willis. 1970. Fertility Levels and Lime Status of Soils in Louisiana. La. Agric. Expt. Sta. Bul. 644.
8. Chapman, H. D. 1966. Diagnostic Criteria for Plants and Soils. Univ. of Calif. Div. of Agric. Sci.
9. Cibes, Hector, and George Samuels. 1957. Mineral Deficiency Symptoms Displayed by Sweet Potato Plants Grown Under Controlled Conditions. Puerto Rico Agric. Expt. Sta. Tech. Paper 20.
10. Edmond, J. B., and H. J. Sefick. 1938. A Description of Certain Nutrient Deficiency Symptoms of the Porto Rico Sweet Potato. Proc. Amer. Soc. Hort. Sci. 36:544-549.
11. Fiskell, F. G. A., C. C. Hortenstine, H. L. Carver, and H. W. Lundy. 1958. Aluminum Studies on Some North and Central Florida Soils. Soil and Crop Sci. Soc. Fla. Proc. 18:166-178.
12. Foy, C. D., A. L. Fleming, and W. H. Arminger. 1969. Differential Tolerance of Cotton Varieties to Excess Manganese. Agron. Jou. 61:690-694.
13. Gallager, R. A. 1967. Manganese Toxicity in Celery. Nature 216:391-396.
14. Grasmanis, V. O., and G. W. Leeper. 1966. Toxic Manganese in Near-Neutral Soils. Plant and Soil 25:4-48.
15. Greig, J. F., and F. W. Smith. 1960. Some Effects of Various Levels of Calcium, Potassium, Magnesium, and Sodium on Sweet Potato Plants Grown in Nutrient Solution. Proc. Amer. Soc. Hort. Sci. 75:561-569.
16. Hale, J. B., and S. G. Heintze. 1946. Manganese Toxicity Affecting Crops on Acid Soils. Nature 157:554.
17. Hartman, J. D., and R. W. Samson. 1940. Effect of Soil Reaction on Soil Rot of Sweet Potatoes. Phytopath. 30:8-9.
18. Heddleson, M. R., M. O. McLean, and E. O. N. Holoway-Chuck. 1960. Aluminum in Soils. IV. The Role of Aluminum in Soil Acidity. Soil Sci. Soc. Amer. Proc. 24:91-94.

19. Hooker, W. J., and L. E. Peterson. 1952. Sulfur Soil Treatment for Control of Sweet Potato Soil Rot Incited by *Streptomyces ipomoea*. Phytopath. 42:583-591.

20. Hussain, M. S. 1970. Extractable Aluminum Content in Some Hawaiian Soils. Pak. Jou. Sci. In. Res. 12:217-221.

21. Jackson, M. L. 1960. Exchangeable Metallic Cation Determination for Soils. Soil Chemistry Analysis: 86-87.

22. Jacobson, H. G. M., and T. R. Swanback. 1932. Manganese Content of Certain Connecticut Soils and Its Relation to the Growth of Tobacco. Jou. Amer. Soc. Agron. 24:327-345.

23. Jones, L. G. 1953-75. Unpublished Data.

24. Kumada, K., and T. Asami. 1958. A New Method for Determining Ferrous Iron in Paddy Soils. Soil and Plant Food 3:187-193.

25. Lohnis, M. P. 1960. Manganese Toxicity in Field and Garden Crops. Plant and Soil 3:193-221.

26. Martin, W. J., L. G. Jones, and T. P. Hernandez. 1967. Sweet Potato Soil Rot Development in Olivier Silt Loam Soil as Affected by Annual Applications of Lime or Sulfur Over a Seven-Year Period. Plant Dis. Rep. 51 (4):271-275.

27. McCool, M. M. 1935. Effect of Light Intensity on the Manganese Content of Plants. Boyce Thompson Institute Contrib. 7:427-437.

28. McLean, F. T., and B. E. Gilbert. 1927. The Relative Aluminum Tolerance of Crop Plants. Soil Sci. 24:163-174.

29. Medappa, K. C., and M. M. Dana. 1970. Tolerance of Cranberry Plants to Manganese, Iron, and Aluminum. Jou. Amer. Soc. Hort. Sci. 95:107-110.

30. Millikan, C. R. 1947. Effects of Molybdenum on the Severity of Toxicity Symptoms in Flax Induced by an Excess of Either Manganese, Zinc, Copper, Nickel, or Cobalt in the Nutrient Solution. Jou. Australian Inst. Agric. Sci. 13:180-186.

31. Mishra, U. N., and J. D. Kelly. 1967. Manganese Nutrition of Sweet Potatoes in Relation to Manganese Content, Deficiency Symptoms, and Growth. Agron. Jou. 59:578-581.

32. Morris, H. D., and W. H. Pierre. 1949. Minimum Concentration of Manganese Necessary for Injury to Various Legumes in Culture Solution. Agron. Jou. 41:107-113.

33. Neal, D. C., and H. C. Lovett. 1938. Further Studies of Crinkle-Leaf, a Disorder of Cotton Plants Prevalent in Lintonia and Olivier Silt Loam Soils of Louisiana. Phytopath. 28:582-587.

34. Person, L. H. 1964. Soil Rot of Sweet Potatoes and Its Control With Sulfur. La. Agric. Exp. Sta. Bul. 408.

35. Person, L. H. and W. J. Martin. 1940. Soil Rot of Sweet Potatoes in Louisiana. Phytopath. 30:913-926.

36. Poole, R. R. 1922. Recent Investigations on the Control on Three Important Field Diseases of Sweet Potatoes. New Jersey Agric. Expt. Sta. Bul. 365.

37. Pope, T. E., and E. N. O'Rourke. 1962. Unpublished Data on Chrysanthemum. La. Agric. Expt. Sta.

38. Rahman, Z. A. 1974. Tomato Plant Growth on Acidified Olivier Soil. M. S. Thesis. La. State University.

39. Rees, W. J., and G. H. Sidrak. 1961. Interrelationships of Aluminum and Manganese Toxicities Toward Plants. Plant and Soil 14:101-117.

40. Russell, E. W. 1961. Soil Conditions and Plant Growth. John Wiley and Sons, Ltd., New York, N.Y.

41. Sherman, G. D., and D. K. Fujimoto. 1946. The Effect of the Use of Lime, Soil Fumigants, and Mulch on the Solubility of Manganese in Hawaiian Soils. Soil Sci. Soc. Amer. Proc. 11:206.

42. Spence, J. A., and N. Ahmed. 1967. Plant Nutrient Deficiencies and Related Tissue Composition of the Sweet Potato. Agron. Jou. 59:59-62.

43. Steinbauer, C. E., and J. H. Beattie. 1939. Influence of Lime and Calcium Chloride Applications on Growth and Yield of Sweet Potatoes. Proc. Amer. Soc. Hort. Sci. 36:526-532.

44. Sturgis, M. B. 1960. Personal Communication.

45. Tisdale, S. L., and B. R. Bertramson. 1950. Elemental Sulfur and Its Relationship to Manganese Availability. Soil Sci. Amer. Proc. 14:131-137.

46. Vogel, A. I. 1960. Quantitative Inorganic Analysis. 2nd ed. Longmans, London, England.

47. Vose, P. B., and P. J. Randall. 1962. Resistance to Aluminum and Manganese Toxicity in Plants Related to Variety and Cation Exchange Capacity. Nature 196:85-86.

48. Yaun, T. L. 1965. A Survey of Aluminum Status in Florida Soils. Soil and Crop Sci. Soc. Fla. Proc. 25:143-152.

49. Yaun, T. L., and F. G. A. Fiskell. 1959. Aluminum Studies: II. The Extraction of Aluminum From Some Florida Soils. Soil Sci. Soc. Amer. Proc. 23:202-205.

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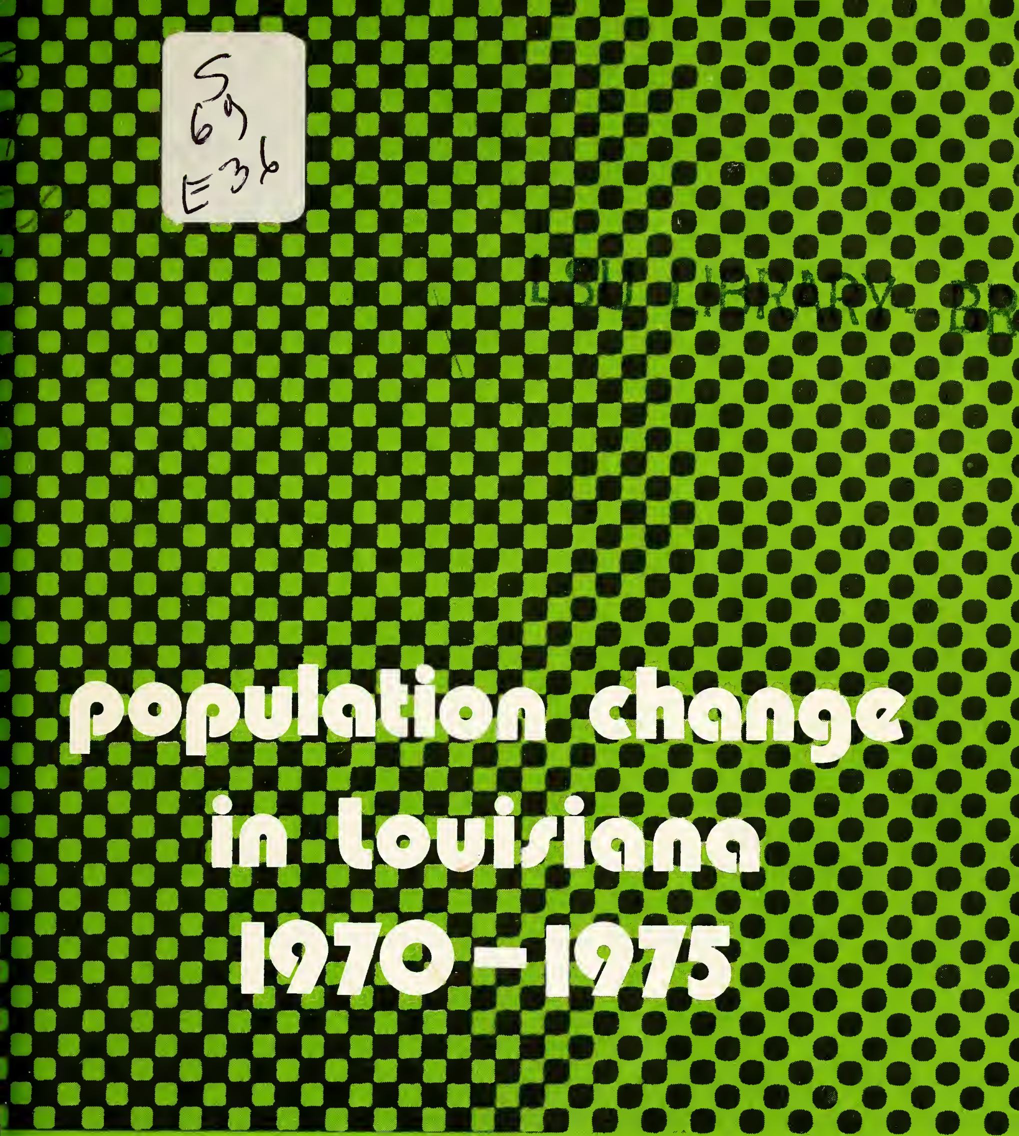

population change in Louisiana 1970-1975

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Bulletin No. 705

October 1977

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Population Change in Louisiana

1970 - 1975

LISANDRO PEREZ AND MAISY L. CHENG*

INTRODUCTION

Rapid social change has become a prominent fact of American social life in the latter part of this century. Transformations in various aspects of our demographic system have occurred in the span of very few years. The alterations in our national population picture prompted Congress in 1976 to pass a bill establishing the mid-decade census starting in 1985; the traditional decennial enumeration was simply not providing census data often enough to keep pace with the dynamics of our population. Another concern is for up-to-date data which give us indications of changes occurring in the U.S. population during intercensal periods. The Current Population Reports are a prime example of that concern on the part of the U. S. Bureau of the Census. These fairly reliable (Beale, 1976, p. 953) intercensal estimates permit federal, state, and local officials, as well as individual citizens, to keep abreast of demographic trends which could affect them.

The intention of the authors of this report is to present an analysis of the estimates of the changes occurring since 1970, specifically in the population of Louisiana. The purpose of the report is not only to inform the state's officials and citizens of the direction of current trends, but to provide explanations for those trends, and to determine their significance. In fulfilling these goals, emphasis is placed on the answers to two questions: (1) How do changes since 1970 compare with the trends of the previous intercensal period (1960-1970)? (2) What are the demographic factors that account for the post-1970 trends? The analysis of the demographic factors involves an assessment of the relative importance of the three demographic processes which, directly and exclusively, determine population change: fertility, mortality, and migration.

The introductory section of this report is devoted to a discussion of the sources of data. The presentation of the findings which follows is divided into three sections. The first is brief, devoted exclusively to examining recent changes in the total population of the state. Section two deals with differences between various residence categories (primarily persons living in metropolitan areas versus persons living in nonmetropolitan areas) and their rates of change. The analysis of residence differentials is of particular interest in view of recent findings relative to a reversal in migration patterns at the national level. The final section examines variations in the rates of population change among the 64 parishes of Louisiana.

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SOURCES OF DATA

The principal sources of data for this study were the publications of the Federal-State Cooperative Program, administered by the U. S. Bureau of the Census as part of the bureau's Current Population Reports. These publications include, for every year since 1970, estimates of the number of inhabitants, births, deaths, and net migration in each state and county of the United States. The estimates were derived from a wide assortment of data found in vital statistics, school enrollments, and Social Security, Medicare, and income tax records.

The specific report used most extensively in this study was No. 75-18 of Series P-26, released in March of 1976 and entitled "Estimates of the Population of Louisiana Parishes and Metropolitan Areas: July 1, 1974 and 1975."[1]

CHANGES IN THE TOTAL POPULATION OF THE STATE

From April 1, 1970 to June 30, 1975, it is estimated that the population of the state grew from 3,642,463 to 3,790,500, an increase of 148,037 inhabitants, or 4.1 percent. The annual rate of growth for the period was 0.76, a rate which, if continued, will mean that the state by 2080 will have twice the number of inhabitants it had in 1975.

The state's population increased during the 5-year period only because there was a surplus of births over deaths. Otherwise, it would have decreased, for Louisiana lost population in the exchange of migrants with other states. Net migration (the difference between those moving in and moving out of the state) from 1970 to 1975 totaled −35,188. Births numbered 359,729, while deaths amounted to 176,504. The resulting natural increase of 183,225 inhabitants far exceeded the migration losses.

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[1] The Current Population Report mentioned does not contain data for the decade of the 1960's, data which are necessary to analyze trends. Most of that information was compiled and published in a Louisiana Agricultural Experiment Station Bulletin (Paterson and Bertrand, 1972), which was devoted to population changes in the state from 1950 to 1970. In addition, estimates of net migration for the 1960 to 1970 decade were taken from a recent publication of the Economic Research Service of the U.S. Department of Agriculture (Bowles and Lee, 1975).

RESIDENCE DIFFERENTIALS

Introduction

The tendency of the U.S. population to concentrate in large metropolitan centers has been a pervasive trend during most of the 20th century. The profound impact of this trend on the development of American society has been widely recognized and documented. Furthermore, social scientists, as well as the general public, had come to believe that the urbanization trend would continue unabated into the foreseeable future.

It was therefore with considerable interest that sociologists and demographers noted the results of a recent study released by the U.S. Department of Agriculture.[2] The findings showed that from 1970 to 1973, nonmetropolitan counties grew at a faster rate than metropolitan counties. The rate of growth for the former was 4.2 percent, while for the latter it was 2.9. Beale, the author of the report, noted that trends during the period from 1960 to 1970 revealed that nonmetropolitan areas were starting to hold their own, retaining more population than they had in the past. But no one really expected that the growth rate of those areas would ever exceed the rate of population increase in metropolitan areas. In addition to this overall conclusion, Beale went further and examined differences in the growth rates of various categories of nonmetropolitan counties (according to their proximity to metropolitan counties) and presented explanations for the differentials in rates.

This section of the present study is concerned with comparing national demographic trends with the population trends of Louisiana. This particular analysis takes on special significance in view of Beale's observation that in addition to the Great Plains the one other major area of the United States which was not following the national trend was the Mississippi Delta (Beale, 1975, p.7). If this was true for Louisiana, then why wasn't the state following the national pattern?

The analysis that follows was guided by, although not limited to, the various conclusions reached by Beale in his examination of the national data. These conclusions can be regarded as hypotheses that were tested utilizing the data on Louisiana:

1. Since 1970, the population in nonmetro counties has grown at a faster rate than the population in metro counties.
2. Since 1970, the population in nonmetro counties that are adjacent

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[2] The study was conducted by Calvin L. Beale of the Economic Research Service, U. S. Department of Agriculture, and published in June of 1975 in a bulletin entitled: *The Revival of Population Growth in Nonmetropolitan America.* Since the appearance of that publication, further research by Beale and others has confirmed the basic findings (Beale, 1976; Tucker, 1976; Morrison and Wheeler, 1976; Wardwell, 1976).

to metro counties has grown at the fastest rate, faster than the population in either nonadjacent nonmetro counties or in metro counties.

3. Since 1970, the population in nonadjacent nonmetro counties has grown at a faster rate than the population in metro counties.

4. Since 1970, the population in the more urbanized nonmetro counties has grown at a rate that did not exceed the growth rate of the remainder of the nonmetro population.

5. Although completely rural nonmetro counties had been losing population during the decade of the 1960's, since 1970 they have reversed that trend, increasing the number of their inhabitants. The rate of that growth, however, was slower than the rate for the remainder of the nonmetro population.

6. Although nonmetro counties had been losing population through migration in the decade of the 1960's, since 1970 they have experienced positive net migration. This shift has occurred in both the adjacent and nonadjacent counties, but it is more pronounced among the latter.

7. Since 1970, the gains in population made through migration by the more urbanized nonmetro areas were not as high as the gains in population made through migration by the remainder of the nonmetro counties.

8. Since 1970, the gains in population made through natural increase by the more urbanized nonmetro areas were higher than the gains in population made through natural increase by the remainder of the nonmetro counties.

9. Given their low rates of natural increase, the growth of population since 1970 in completely rural counties has principally been a result of inmigration.

10. In comparison with the period from 1960 to 1970, metro counties have experienced since 1970 a drop in the amount of population they have gained through migration.

The scope of the present analysis is strictly demographic; that is, explanations for the observed trends are sought, as noted earlier, in the demographic variables that directly affect population growth: fertility, mortality, and migration. Consequently, Beale's conclusions with respect to the social and economic variables that may be associated with those demographic trends are omitted.

Approach

Since comparisons among various residential categories are basic to this analysis, it is important to specify the criteria that were utilized for dividing the state into these categories. Metropolitan parishes are those within the boundaries of the state's seven Standard Metropolitan Statistical Areas (SMSA's) in 1975. It should be noted that not all of these parishes were metropolitan prior to 1975. Nevertheless, in order to make valid comparisons with earlier periods, they were consistently placed in the metropolitan category throughout the study (see Figure 1).

Further subdivision of metropolitan areas was made by using the subcategories of metropolitan counties suggested in a USDA publication (Hines et al., 1975, p. 4). These more delimited categories, their definitions, and the Louisiana parishes that could be categorized under each in 1975 are listed below:

1. Greater metropolitan (parishes contained within SMSA's of 1 million or more inhabitants): the parishes of the New Orleans SMSA (Orleans, Jefferson, St. Bernard, and St. Tammany).

2. Medium metropolitan (parishes contained within SMSA's of 250,000 to 999,999 inhabitants): the parishes of the Baton Rouge and Shreveport SMSA's (Ascension, East Baton Rouge, Livingston, West Baton Rouge, Bossier, Caddo, and Webster).

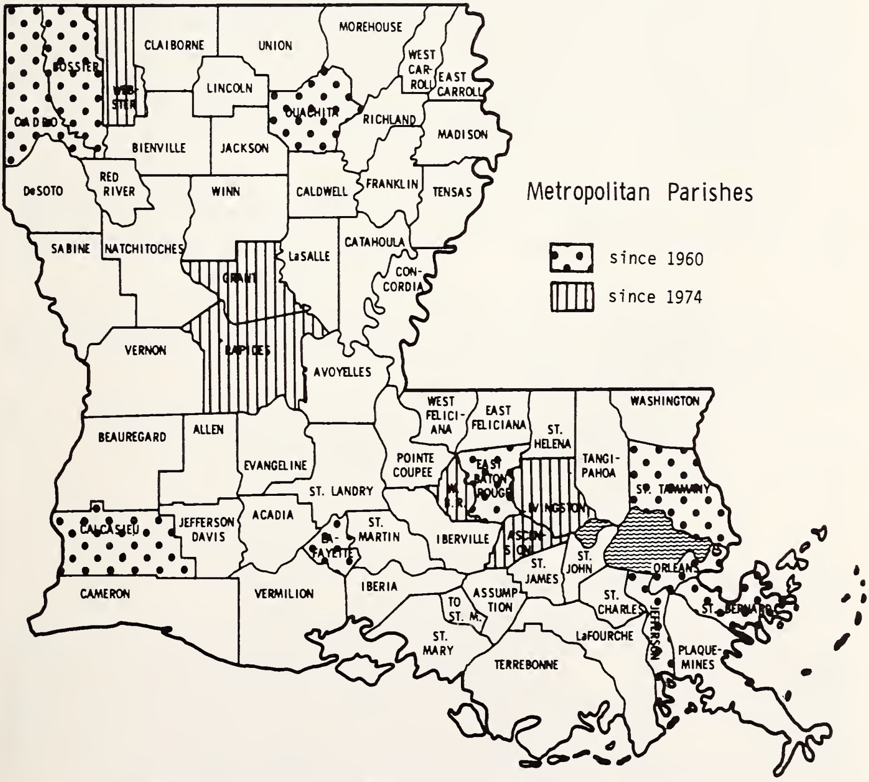

Figure 1. — Metropolitan parishes of Louisiana, 1975.

3. Small metropolitan (parishes contained within SMSA's of less than 250,000 inhabitants): the parishes of the Alexandria, Lafayette, Lake Charles, and Monroe SMSA's (Grant, Rapides, Lafayette, Calcasieu, and Ouachita).

Nonmetropolitan parishes are, of course, those not contained within SMSA's. Further subdivisions of this broad category again follow the suggestions of Hines, et al. (1975, p. 4) and are based on two criteria: (1) proximity to metropolitan counties, and (2) the size of the urban population of each parish. These more specific groupings, their definitions, and the Louisiana parishes that could be categorized under each in 1975 are as follows:

1. Urbanized adjacent (parishes contiguous to SMSA's and having an aggregate urban population of at least 20,000 inhabitants): Acadia, Iberia, Lafourche, Lincoln, St. Landry, Tangipahoa, Vernon, and Washington.
2. Urbanized nonadjacent (parishes not contiguous to SMSA's and having an aggregate urban population of at least 20,000 inhabitants): St. Mary and Terrebonne.
3. Less urbanized adjacent (parishes contiguous to SMSA's and having an aggregate urban population of 2,500 to 19,999 inhabitants): Allen, Avoyelles, Beauregard, Bienville, Claiborne, DeSoto, East Feliciana, Evangeline, Iberville, Jackson, Jefferson Davis, Morehouse, Natchitoches, Plaquemines, Pointe Coupee, Richland, St. Charles, St. James, St. John the Baptist, St. Martin, Union, Vermilion, and Winn.
4. Less urbanized nonadjacent (parishes not contiguous to SMSA's and having an aggregate urban population of 2,500 to 19,999 inhabitants): Catahoula, Concordia, East Carroll, Franklin, Madison, and Sabine.
5. Totally rural adjacent (parishes contiguous to SMSA's and having no urban population): Assumption, Caldwell, Cameron, LaSalle, Red River, St. Helena, and West Feliciana.
6. Totally rural nonadjacent (parishes not contiguous to SMSA's and having no urban population): Tensas and West Carroll.

Residential Differentials in Population Change

The number of inhabitants in Louisiana in 1975 and 1970 by major residence categories — metropolitan versus nonmetropolitan residence with the latter further subdivided according to proximity to metro parishes — is shown in Table 1. Changes occurring in the 5-year period are also shown in the table. These changes are expressed in absolute terms, as a percent of the 1970 population, and as an annual growth rate.

Table 1.—Percent Change and Annual Growth Rate of the Population by Major Residence Categories, Louisiana, 1970-1975

Residence Category	Total Population 1975	Total Population 1970	Change 1970-1975[b] Number	Change 1970-1975[b] % Change	Change 1970-1975[b] Annual Growth Rate
Louisiana	3,790,500	3,642,463[a]	148,037	4.1	0.76
Metropolitan	2,388,600	2,260,118	128,482	5.7	1.06
Nonmetropolitan	1,401,900	1,382,345	19,555	1.4	0.27
Adjacent	1,135,600	1,117,904	17,696	1.6	0.30
Nonadjacent	266,300	264,441	1,859	0.7	0.13

[a] The total for the state shown here includes all corrections to the 1970 Census made subsequent to the release of the official count. The official 1970 Census count for Louisiana was 3,643,180.

[b] The change is actually between April 1, 1970 and June 30, 1975, resulting in a time interval of 5.25 years.

Source: Computed from data obtained from the U. S. Bureau of the Census, *Current Population Reports,* Series P-26, No. 75-18, March, 1976.

Differences by residence were found, but it is apparent that the state is not following the national trend. In contrast to Beale's findings on the total U.S. population, the metropolitan areas of Louisiana grew at a considerably faster rate than nonmetropolitan areas. Additionally, the nonmetropolitan population in parishes adjacent to SMSA's grew at a considerably slower rate than the metropolitan population and only slightly faster than the rest of the nonmetropolitan population. The nonmetro population in nonadjacent parishes exhibited by far the slowest rate of growth. Perhaps the best way to summarize the data in Table 1 is to say that the first three national trends that were listed have definitely not been echoed in the population of Louisiana. In fact, the trends in this state are exactly the opposite of national patterns.

Since the national study made comparisons between the period since 1970 and the decennial period just before 1970 to demonstrate that recent patterns constituted a reversal of previous trends, the same procedure was used in analyzing the data for Louisiana. Annual growth rates for the 1970-1975 period and corresponding rates for 1960-1970 are shown in Table 2. The biggest different between the two time periods was that from 1970 to 1975 the population of the state grew at a slower rate than during the preceding decennial period. This pattern was reflected in all the residence categories. Despite the overall pattern of higher growth rates in the earlier period, however, it is apparent that in Louisiana the nonmetro-nonadjacent annual rate for 1970-1975 dropped much more than did the rates for the other residence groups. In fact, in the 1960-1970 period, the growth rate of the nonmetro-nonadjacent dwellers was considerably higher than the rate for the adjacent population. But in the subsequent period, the rate for the former dropped from 0.85 to 0.13, considerably lower than the corresponding rate for the adjacent population. It can be

Table 2.—Annual Growth Rate of the Population by Major Residence Categories, Louisiana, 1970-1975 and 1960-1970

Residence Category	Annual Growth Rate 1970-1975	Annual Growth Rate 1960-1970
Louisiana	0.76	1.12
Metropolitan	1.06	1.51
Nonmetropolitan	0.27	0.52
Adjacent	0.30	0.45
Nonadjacent	0.13	0.85

Source: Computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports,* Series P-26, No. 75-18, March 1976, and *U.S. Census of Population,* 1960, PC (1)-A20, Louisiana.

concluded that, overall, from 1970 to 1975 the relative standing of the various residence categories in terms of their growth rates was not very different from the situation during the preceding decade. The only exception was the tremendous drop in the growth rate of the nonmetro-nonadjacent population, making that category the one with the lowest rate in the recent 5-year period. This, of course, stands in obvious contrast to the national pattern.

It would be of interest to examine the implications which the growth rates in Table 2 have had for the redistribution of the population of the state into the major residence categories. Since 1960 there has been a slight, yet steady, increase in the proportion of the population of Louisiana residing in metropolitan parishes (Table 3). During the same year both subcategories of the nonmetropolitan population decreased in relative importance.

Using the criteria specified earlier, both metropolitan and nonmetropolitan populations can be subdivided to examine in more detail the process of population change in Louisiana from 1970 to 1975. In Table 4, the metropolitan population is divided according to the size of individual metrolitan areas, with each SMSA listed separately. For the New Orleans SMSA a further distinction is made between the core parish (Orleans) and

Table 3.—Distribution of the Population of Louisiana by Major Residence Categories, 1975, 1970, and 1960

Residence Category	1975 Number	1975 %	1970 Number	1970 %	1960 Number	1960 %
Louisiana	3,790,500	100.0	3,642,463	100.0	3,257,022	100.0
Metropolitan	2,388,600	63.0	2,260,118	62.0	1,944,834	59.7
Nonmetropolitan	1,401,900	37.0	1,382,345	38.0	1,312,188	40.3
Adjacent	1,135,600	30.0	1,117,904	30.7	1,069,194	32.8
Nonadjacent	266,300	7.0	264,441	7.3	242,994	7.5

Source: Computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports,* Series P-26, No. 75-18, March 1976, and *U.S. Census of Population:* 1960, PC(1)-A20, Louisiana

Table 4.—Percent Change in the Metropolitan Population of Louisiana by Specific Residence Categories, 1970 - 1975

	Total Population		Change, 1970-1975	
Residence Category	1975	1970	Number	%
Louisiana	3,790,500	3,642,463	148,037	4.1
Metropolitan	2,388,600	2,260,118	128,482	5.7
Greater Metro Area (New Orleans SMSA)	1,094,300	1,046,470	47,830	4.6
Core Parish	564,300	593,471	–29,171	–4.9
Fringe Parishes	530,000	452,999	77,001	17.0
Medium Metro Areas	757,100	709,454	47,646	6.7
Baton Rouge SMSA	411,400	375,628	35,772	9.5
Shreveport SMSA	345,700	333,826	11,874	3.6
Smaller Metro Areas	537,200	504,194	33,006	6.5
Alexandria SMSA	135,800	131,749	4,051	3.1
Lafayette SMSA	125,300	111,643	13,657	12.2
Lake Charles SMSA	150,500	145,415	5,085	3.5
Monroe SMSA	125,600	115,387	10,213	8.8

Source: Computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports*, Series P-26, No. 75-18, March, 1976.

the fringe parishes (Jefferson, St. Bernard, and St. Tammany). Perhaps the most interesting observation that can be made from information in the table is that the largest SMSA grew at a slower rate than the rest of the metropolitan population and that it was the loss of population experienced by the core parish that was solely responsible for that lower rate of change. The fringe parishes of the New Orleans SMSA grew at a pace that exceeded the growth rate of each of the metro areas of the state.

The population of medium and smaller metro parishes, particularly the former, exhibited increases that far outpaced the growth rate of the entire New Orleans metro area. There was, however, substantial variation within those categories. Lafayette grew 12.2 percent in just 5 years. Baton Rouge and Monroe also experienced increases that were considerably above the growth rate of the entire metropolitan population. The rest of the SMSA's, however, each had a lower growth rate than that of the total metropolitan population. In fact, the growth rate of Shreveport, Alexandria, and Lake Charles was even below that of the New Orleans SMSA.

The counterpart of Table 4 for the nonmetropolitan population is Table 5. It is clear that of the nonmetro parishes, the most urbanized ones (both adjacent and nonadjacent) experienced the greatest increases from 1970 to 1975. This, of course, is not in agreement with Beale's conclusion that the population in the more urbanized nonmetro counties grew at a rate that did not exceed the growth rate of the rest of the nonmetro population. By far the greatest percent increase in the nonmetro category was that of the nonadjacent urbanized parishes.

Table 5.—Percent Change in the Nonmetropolitan Population of Louisiana by Specific Residence Categories, 1970-1975

	Total Population		Change, 1970-1975	
Residence Category	1975	1970	Number	%
Louisiana	3,790,500	3,642,463	148,037	4.1
Nonmetropolitan	1,401,900	1,382,345	19,555	1.4
Adjacent	1,135,600	1,117,904	17,696	1.6
Urbanized	464,400	454,267	10,133	2.2
Less Urbanized	590,000	583,216	6,784	1.2
Totally Rural	81,200	80,421	779	1.0
Nonadjacent	266,300	264,441	1,859	0.7
Urbanized	144,000	136,801	7,199	5.3
Less Urbanized	101,100	104,880	–3,780	–3.6
Totally Rural	21,200	22,760	–1,560	–6.8

Source: Computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports*, Series P-26, No. 75-18, March, 1976.

The changes in population registered by the totally rural parishes of Louisiana also stand in sharp contrast to national patterns. Whereas Beale found that totally rural nonmetro counties had started to grow after at least a decade of losing population, in Louisiana only adjacent rural parishes exhibited population growth, and even then it was slight. The rural nonadjacent parishes (Tensas and West Carroll) together lost 6.8 percent of their inhabitants in just 5 years. Combining the two totally rural categories (adjacent and nonadjacent) yields a population loss of 0.8 percent. In addition to the totally rural parishes, the less-urbanized-nonadjacent parishes were also population losers from 1970 to 1975.

In summary, the data for Louisiana reveal that the state as a whole is an exception to the national pattern described by Beale. Metropolitan areas, particularly the small and medium-sized SMSA's, have continued to exhibit higher growth rates than nonmetropolitan areas. Among the latter, the nonadjacent and totally rural parishes continue to be areas of either population loss or very little growth. Contrary to the national trend, the rate of increase in the population of nonmetro-nonadjacent areas was lower in 1970-1975 than during the 10-year period preceding 1970.

Components of Change

The first step toward understanding the growth trends observed in the previous section is an analysis of the changes occurring during the same period in the three components of population change: fertility, mortality, and migration. To simplify the present analysis, the effect of fertility and mortality will be measured by natural increase, which is the difference between the number of births and deaths. The importance of migration will be ascertained through data on net migration, which are arrived at by subtracting the number of persons moving out from the number of persons moving into the area in question.

The Current Population Report No. 75-18 of Series P-26 not only contains estimates of the total population of each parish in 1975, but also estimates of the components of change from 1970 to 1975. The figures from that source on the number of births and deaths are based on reported vital statistics from April 1, 1970 to December 31, 1975, with extrapolations to June 30, 1975. The estimate of net migration was obtained by the Census Office in a residual manner, by subtracting the natural increase figure from estimates of total population change during the 5-year period.

After securing for each parish the number of births and deaths recorded from April 1, 1970 to June 30, 1975, it was possible to adjust estimates found in the Current Population Reports in accordance with the actual data.[3] Therefore, the figures used here on both natural increase and net migration can probably be regarded as more precise than those found in P-26 No. 75-18. While the adjustments were not of a great magnitude, the increased accuracy could be crucial when examining the population dynamics of relatively small populations.

The state's growth trends from 1970 to 1975 are shown in Table 6. Metropolitan parishes gained proportionately more population through natural increase than did the nonmetropolitan parishes as a whole. It can be seen, however, that the nonmetro-nonadjacent parishes had a rate of natural increase that was not only substantially above the adjacent category, but also slightly above the rate for metro areas. In net migration,

Table 6.—Components of Change in the Population of Louisiana, by Major Residence Categories, 1970-1975

			Natural Increase 1970-1975		Net Migration 1970-1975	
Residence Category	Births	Deaths	Number	Rate [a]	Number	Rate [b]
Louisiana	359,729	176,504	183,225	9.6	–35,188	–0.97
Metropolitan	227,283	107,935	119,348	10.1	9,134	0.40
Nonmetropolitan	132,446	68,569	63,877	8.8	–44,322	–3.21
Adjacent	104,617	55,965	48,652	8.3	–30,956	–2.77
Nonadjacent	27,829	12,604	15,225	11.0	–13,366	–5.05

[a] The rate of average annual natural increase was computed by dividing the amount of natural increase from 1970 to 1975 by the total population in that category in 1970. The result was then multiplied by 1,000, and then divided by 5.25.

[b] The rate of net migration was computed by dividing the amount of net migration from 1970-1975 by the total population in that category in 1970, and then multiplied by 100.

Source: Computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports*, Series P-26, No. 75-18, March, 1976; Office of the Public Health Statistics, *Public Health Sputics*, 1974 Series, No. 4 and 1975 Series No. 2, and *Vital Statistics of Louisiana*, 1971, 1972 and 1973.

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[3] The cooperation of the Louisiana Office of Public Health Statistics, and its former director, Ernie Atkins, made it possible to secure these unpublished data.

however, the nonadjacent parishes were the big losers. In fact, all nonmetro areas lost population through migration. Metro areas were the only ones experiencing positive net migration, and then only slightly. It is not surprising that the state as a whole lost population through migration during those 5 years. Returning to Beale's conclusions, it is obvious that nonmetropolitan areas of Louisiana have not switched to positive net migration and that nonadjacent parishes have experienced the greatest population losses through migration. It is not difficult to see why, despite their high rates of natural increase, these nonadjacent parishes managed to exhibit the slowest rates of population growth during the 5-year period in question.

Components of change for the subdivisions of the metropolitan population are presented in Table 7. The highest rates of both natural increase and net migration were experienced by the three SMSA's that had exhibited the highest growth rate: Lafayette, Baton Rouge, and Monroe. The rates for Lafayette were particularly high. Interestingly, New Orleans grew during this period exclusively from natural increase, since it actually lost population through migration. Once again, however, the distinction between the core and fringe parishes of that SMSA is a meaningful one, for Orleans Parish experienced negative net migration while the fringe

Table 7.— Components of Change in the Metropolitan Population of Louisiana by Specific Residence Categories, 1970-1975

			Natural Increase 1970-1975		Net Migration 1970-1975	
Residence Category	Births	Deaths	Number	Rate[a]	Number	Rate[b]
Louisiana	359,729	176,504	183,225	9.6	–35,188	–0.97
Metropolitan	227,283	107,935	119,348	10.1	9,134	0.40
Greater Metro Area (New Orleans SMSA)	102,681	53,613	49,068	8.9	–1,238	–0.12
Core Parish	55,848	36,536	19,312	6.2	–48,483	–8.17
Fringe Parishes	46,833	17,077	29,756	12.5	47,245	10.43
Medium Metro Areas	72,705	31,557	41,148	11.0	6,498	0.92
Baton Rouge SMSA	38,518	14,704	23,814	12.1	11,958	3.18
Shreveport SMSA	34,187	16,853	17,334	9.9	–5,460	–1.64
Smaller Metro Areas	51,897	22,765	29,132	11.0	3,874	0.77
Alexandria SMSA	13,207	7,149	6,058	8.8	–2,007	–1.52
Lafayette SMSA	11,657	3,879	7,778	13.3	5,879	5.26
Lake Charles SMSA	14,278	6,127	8,151	10.7	–3,066	–2.11
Monroe SMSA	12,755	5,610	7,145	11.8	3,068	2.66

[a] The rate of average annual natural increase was computed by dividing the amount of natural increase from 1970 to 1975 by the total population in that category in 1970. The result was then multiplied by 1,000, and then divided by 5.25.

[b] The rate of net migration was computed by dividing the amount of net migration from 1970-1975 by the total population in that category in 1970, and then multiplied by 100.

Source: Computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports*, Series P-26, No. 75-18, March 1976; Office of the Public Health Statistics, *Public Health Statistics*, 1974 Series, No. 4 and 1975 Series No. 2, and *Vital Statistics of Louisiana*, 1971, 1972 and 1973.

parishes exhibited the highest rate of net migration of all residence classes in Table 7.

The three SMSA's that had exhibited the slowest rates of growth (Shreveport, Alexandria, and Lake Charles) also had to depend exclusively on natural increase for growth in their population. They also lost population in the exchange of migrants with other areas. Of all metro areas, Lakes Charles was the SMSA which, on a relative basis, sustained the greatest losses through migration. It was able to compensate for these losses, however, with one of the highest rates of natural increase.

The components of change for the subdivisions of the nonmetropolitan population are presented in Table 8. It should be noted that every subcategory of the nonmetropolitan population of Louisiana lost population through migration in the period in question. There was little variation between the migration rates for the categories of the adjacent population: all three of them were close to the rate for the nonmetropolitan population as a whole. Within the nonadjacent category, however, there was a real disparity. Whereas losses of the nonadjacent-urbanized parishes were at about the same level as those of the adjacent population, the rates for the less urbanized and totally rural nonadjacent parishes represented losses of a much greater magnitude. The nonadjacent parishes that are totally rural are particularly noteworthy, for they lost through migration the equivalent of more than 10 percent of their 1970 population. Once again, little evidence was found here of the patterns that prevail nationally. Beale's con-

Table 8.—Components of Change in the Nonmetropolitan Population of Louisiana by Specific Residence Categories, 1970-1975

			Natural Increase 1970-1975		Net Migration 1970-1975	
Residence Category	Births	Deaths	Number	Rate[a]	Number	Rate[b]
Louisiana	359,729	176,504	183,225	9.6	–35,188	–0.97
Nonmetropolitan	132,446	68,569	63,877	8.8	–44,322	–3.21
Adjacent	104,617	55,965	48,652	8.3	–30,956	–2.77
Urbanized	42,363	21,019	21,344	8.9	–11,211	–2.46
Less Urbanized	55,321	30,891	24,430	8.0	–17,646	–3.03
Totally Rural	6,933	4,055	2,878	6.8	–2,099	–2.61
Nonadjacent	27,829	12,604	15,225	11.0	–13,366	–5.05
Urbanized	15,881	5,284	10,597	14.7	–3,398	–2.48
Less Urbanized	9,890	5,993	3,897	7.1	–7,677	–7.32
Totally Rural	2,058	1,327	731	6.1	–2,291	–10.07

[a] The rate of average annual natural increase was computed by dividing the amount of natural increase from 1970 to 1975 by the total population in that category in 1970. The result was then multiplied by 1,000, and then divided by 5.25.

[b] The rate of net migration was computed by dividing the amount of net migration from 1970-1975 by the total population in that category in 1970, and then by 100.

Source: Computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports*, Series P-26, No. 75-18, March, 1976; Office of the Public Health Statistics, *Public Health Statistics*, 1974 Series, No. 4 and 1975 Series No. 2, and *Vital Statistics of Louisiana*, 1971, 1972 and 1973.

clusion, that the gains in population made through migration by the more urbanized metro areas were not as high as the gains in population made through migration by the remainder of the nonmetro counties, simply does not hold true here. In the first place, there were no gains through migration in any of the nonmetropolitan categories, and secondly, the losses of the urbanized parishes were not as great as the losses experienced by the remainder of the nonmetro parishes.

Examining the rates of natural increase, it is clear that the more urbanized nonmetro parishes (both adjacent and nonadjacent) experienced the highest rates of such increases. This means that gains in population made through natural increase by the more urbanized nonmetro areas were higher than gains made through natural increase by the remainder of the nonmetro counties, and is thus far the only one of Beale's findings that finds an echo in Louisiana.

The urbanized-nonadjacent parishes exhibited a rate of natural increase of 14.7, by far the highest of the rates in Table 8. This high rate of natural increase, combined with comparatively low losses through migration, is the reason why more urbanized-nonadjacent parishes exhibited the highest growth rate of all the nonmetro parishes. In contrast, the remainder of the nonadjacent parishes experienced a relatively low natural increase. This somewhat small rate of natural increase, together with heavy migration losses, caused these less urbanized and totally rural parishes to experience a decline in their total populations from 1970 to 1975.

The categories with the lowest rates of natural increase were the totally rural adjacent and nonadjacent parishes. It is probable that these parishes experienced, for some time prior to 1970, a considerable amount of age-selective outmigration that resulted in a subfecund age structure, or an age composition with proportionately few persons in reproductive ages. It is also possible that these rural parishes suffer from higher mortality levels in comparison with the other residence categories. Beale's conclusion that totally rural counties grew principally through migration is not applicable to the situation in Louisiana, where these parishes not only experienced heavy losses through migration, but did not even grow from 1970 to 1975.

Since many of Beale's findings are based upon comparisons between the trends since 1970 and the situation for the decade prior to that year, it is worthwhile to compare the changes in the components of population growth between those two time periods using the data from Louisiana. Annual estimates of natural increase and net migration for each specific category of the metropolitan population are shown in Table 9. The table was drawn to facilitate a comparison between estimates for 1960 to 1970 and those for the period since 1970. These figures were arrived at through the method suggested by Shryock, et al. (1973, p. 608) for contrasting the levels of net migration or natural increase between time periods of unequal length. Following Beale's approach, rates were not computed for

Table 9.—Estimates of Annual Natural Increase and Net Migration for the Metropolitan Population, by Specific Residence Categories, Louisiana, 1970-1975, and 1960-1970

	Estimated Annual Natural Increase		Estimated Annual Net Migration	
Residence Category	1970-1975	1960-1970	1970-1975	1960-1970
Louisiana	34,900	51,640	–6,702	–12,295
Metropolitan	22,733	30,820	1,740	–3,322
Greater Metro Area (New Orleans SMSA)	9,346	13,110	–236	795
Core Parish	3,678	6,811	–9,235	–10,189
Fringe Parishes	5,668	6,299	8,999	10,984
Medium Metro Areas	7,838	10,074	1,238	–1,226
Smaller Metro Areas	5,549	7,636	738	–2,891

Source: Computed from data obtained from the Bureau of the Census, *Current Population Reports, Population Estimates,* Series P-26, No. 75-18, and Karen W. Paterson and Alvin L. Bertrand, *Louisiana's Human Resources, Part V,* Louisiana State University, Agricultural Experiment Station, Bulletin No. 661, April, 1972.

these absolute figures. Caution should be taken, therefore, in comparing the figures in the table. Vertical comparisons, that is, comparisons between residence classes, should not be made since different population bases are involved. The only valid contrasts are those between time periods within each residence category, which is precisely the kind of analysis most suitable for our purposes.

It is apparent that the last conclusion listed (number 10) is not an accurate description of the situation in Louisiana. Metropolitan parishes in Louisiana gained population through migration in the more recent period. In the previous decade, the annual net migration rate indicates these parishes had been losing population in the exchange of inhabitants with other areas. There is little difference between the two time periods with respect to the Greater Metro Area (New Orleans). It is interesting, however, that although the fringe parishes continued to gain population through migration, these gains had apparently leveled off and even dropped slightly. The core parish of Orleans continued to lose inhabitants. It is among the medium and smaller SMSA's that a more noticeable contrast is present. After losing population through migration during the previous decade, the 1970-1975 net migration figures for these parishes were on the positive side.

In terms of differences in natural increase between the two time periods, there was a consistent drop in all parishes in the number of inhabitants that the natural processes contributed annually. The trend most responsible for this was probably the general decline in the birth rate, a decline that intensified after the late 1960's.

Table 10 is the counterpart of Table 9 for the nonmetropolitan population. Unless one wishes to engage in the questionable practice of drawing

Table 10.—Estimates of Annual Natural Increase and Net Migration for the Nonmetropolitan Population, by Specific Residence Categories, Louisiana, 1970-1975 and 1960-1970

	Estimated Annual Natural Increase		Estimated Annual Net Migration	
Residence Category	1970-1975	1960-1970	1970-1975	1960-1970
Louisiana	34,900	51,640	–6,702	–12,295
Nonmetropolitan	12,167	20,820	–8,442	–8,973
Adjacent	9,267	16,174	–5,896	–6,660
Urbanized	4,066	6,752	–2,135	–100
Less Urbanized	4,653	8,438	–3,361	–5,865
Totally Rural	548	984	–400	–695
Nonadjacent	2,900	4,646	–2,546	–2,313
Urbanized	2,019	2,787	–647	–54
Less Urbanized	742	1,542	–1,462	–1,644
Totally Rural	139	317	–437	–615

Source: Computed from data obtained the Bureau of the Census, Current Population Reports, *Population Estimates,* Series P-26, No. 75-18, and Karen W. Paterson and Alvin L. Bertrand, *Louisiana's Human Resources, Part V,* Louisiana State University, Agricultural Experiment Station, Bulletin No. 661, April, 1972.

significance from relatively small numerical differences in the estimates for the two time periods, one must conclude that, overall, the net migration patterns for the recent 5-year period seem to continue the trends established during the 1960-1970 decade. All nonmetro groupings continued their losing tradition into the 1970's.

With respect to natural increase, the pattern exhibited by the metropolitan parishes is also evident in Table 10. There was an overall decline in annual gains made through natural increase. It appears, however, that less urbanized as well as totally rural parishes of both adjacent and nonadjacent categories have experienced a greater drop in annual natural increase than urbanized parishes (both adjacent and non-adjacent) between the two time periods.

PARISH DIFFERENTIALS

Since the 64 parishes of Louisiana are significant civil-administrative divisions, the main concern in this section is to provide interested citizens and local officials with the following information about their respective parishes: (1) What is the latest (1975) estimate of population? (2) What has been the direction and amount of change since the 1970 census? (3) How have the trends in the components of change determined the recent changes in the total population of the parish? (4) How do all these changes compare with the population dynamics of the previous decade (1960-1970)? (5) How do the findings in the previous section with respect to residential differentials help us understand the rates of change in the parish populations?

The total number of inhabitants in each parish in both 1970 and 1975, as well as the amount and percent of change during this 5-year period, are presented in Table 11. The parishes are also ranked in the table according to their total population in 1975 and also according to percent of change. In terms of number of inhabitants in 1975, Orleans was the largest parish with

Table 11.—The Parishes of Louisiana: Number of Inhabitants, 1970 and 1975, and Changes in Population, 1970-1975

	Total Population			Change		
Parish	1970	1975	Rank in 1975	Number	Percent	Rank*
Louisiana	3,642,463	3,790,500		148,037	4.1	
Acadia	52,109	53,100	18	991	1.9	32
Allen	20,794	20,100	42	–694	–3.3	52
Ascension	37,086	40,100	23	3,014	8.1	13
Assumption	19,654	20,000	43	346	1.8	33
Avoyelles	37,751	37,500	25	–251	–0.6	43
Beauregard	22,888	25,600	35	2,712	11.8	6
Bienville	16,024	16,600	48	576	3.6	26
Bossier	63,703	67,700	14	3,997	6.3	18
Caddo	230,184	238,400	4	8,216	3.6	27
Calcasieu	145,415	150,500	5	5,085	3.5	28
Caldwell	9,354	10,100	59	746	8.0	14
Cameron	8,194	8,900	63	706	8.6	11
Catahoula	11,769	11,100	58	–669	–5.7	57
Claiborne	17,024	16,200	50	–824	–4.8	55
Concordia	22,578	21,100	41	–1,478	–6.5	59
DeSoto	22,764	22,800	38	36	0.2	36
East Baton Rouge	285,167	311,400	3	26,233	9.2	8
East Carroll	12,884	11,900	57	–984	–7.6	62
East Feliciana	17,657	16,500	49	–1,157	–6.5	60
Evangeline	31,932	31,800	31	–132	–0.4	42
Franklin	23,946	23,100	37	–846	–3.5	53
Grant	13,671	14,300	55	629	4.6	22
Iberia	57,397	61,400	15	4,003	7.0	16
Iberville	30,746	30,400	32	–346	–1.1	46
Jackson	15,963	15,900	52	–63	–0.4	41
Jefferson	338,229	395,800	2	57,571	17.0	2
Jefferson Davis	29,554	29,800	33	246	0.8	35
Lafayette	111,643	125,300	7	13,657	12.2	5
Lafourche	68,941	72,000	12	3,059	4.4	23
LaSalle	13,295	14,500	53	1,205	9.1	9
Lincoln	33,800	36,100	26	2,300	6.8	17
Livingston	36,511	42,400	21	5,889	16.1	3
Madison	15,065	14,400	54	–665	–4.4	54
Morehouse	32,463	31,900	30	–563	–1.7	48
Natchitoches	35,219	35,700	27	481	1.4	34
Orleans	593,471	564,300	1	–29,171	–4.9	56
Ouachita	115,387	125,600	6	10,213	8.8	10
Plaquemines	25,225	25,900	34	675	2.7	30
Point Coupee	22,002	21,600	40	–402	–1.8	49
Rapides	118,078	121,500	8	3,422	2.9	29

(Continued)

Table 11.—(Continued)

	Total Population			Change		
Parish	1970	1975	Rank in 1975	Number	Percent	Rank*
Red River	9,226	9,220	61.5	–26	–0.3	40
Richland	21,774	21,800	39	26	0.1	37
Sabine	18,638	19,500	45	862	4.6	20
St. Bernard	51,185	57,800	17	6,615	12.9	4
St. Charles	29,550	32,000	29	2,450	8.3	12
St. Helena	9,937	9,300	60	–637	–6.4	58
St. James	19,733	19,600	44	–133	–0.7	44
St. John the Baptist	23,813	24,700	36	887	3.7	25
St. Landry	80,364	79,400	10	–964	–1.2	47
St. Martin	32,453	34,100	28	1,647	5.1	19
St. Mary	60,752	60,600	16	–152	–0.3	39
St. Tammany	63,585	76,400	11	12,815	20.1	1
Tangipahoa	65,875	70,600	13	4,725	7.2	15
Tensas	9,732	8,500	64	–1,232	–12.7	63
Terrebonne	76,049	83,400	9	7,351	9.7	7
Union	18,447	19,300	46	853	4.6	21
Vermilion	43,071	44,200	20	1,129	2.6	31
Vernon	53,794	49,800	19	–3,994	–7.4	61
Washington	41,987	42,000	22	13	0.0	38
Webster	39,939	39,600	24	—339	–0.8	45
West Baton Rouge	16,684	17,500	47	636	3.8	24
West Carroll	13,028	12,700	56	–328	–2.5	51
West Feliciana	10,761	9,200	61.5	–1,561	—14.5	64
Winn	16,369	16,000	51	–369	–2.2	50

*Rank assigned according to percent change, with the highest percent increase assigned the rank of 1, and the highest percent decrease receiving the rank of 64.

Source: Compiled and computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports,* Series P-26, No. 75-18, March, 1976.

564,300 persons. The smallest parish, ranked 64th in 1975, was Tensas, with only 8,500 inhabitants. Jefferson, in the New Orleans SMSA, was the second-largest parish.

Twenty-six parishes, or slightly more than 40 percent, had a smaller population in 1975 than in 1970. The two parishes that experienced the greatest decreases in that period were West Feliciana (−14.5 percent) and Tensas (−12.7 percent). Both are totally rural parishes. In contrast, Jefferson, Lafayette, Livington, St. Bernard, and St. Tammany were the five parishes in the state that increased their population by more than 12 percent during the first half of the 1970 decade. They are all metropolitan parishes.

One question that arises at this point is whether or not parishes with similar rates of change are clustered geographically; that is, are there "belts" or regions of the state that are homogeneous in terms of population change? The percentages found in Table 11 are visually portrayed in Figure 2. Although no clear-cut concentrations or "belts" can be discerned, it can

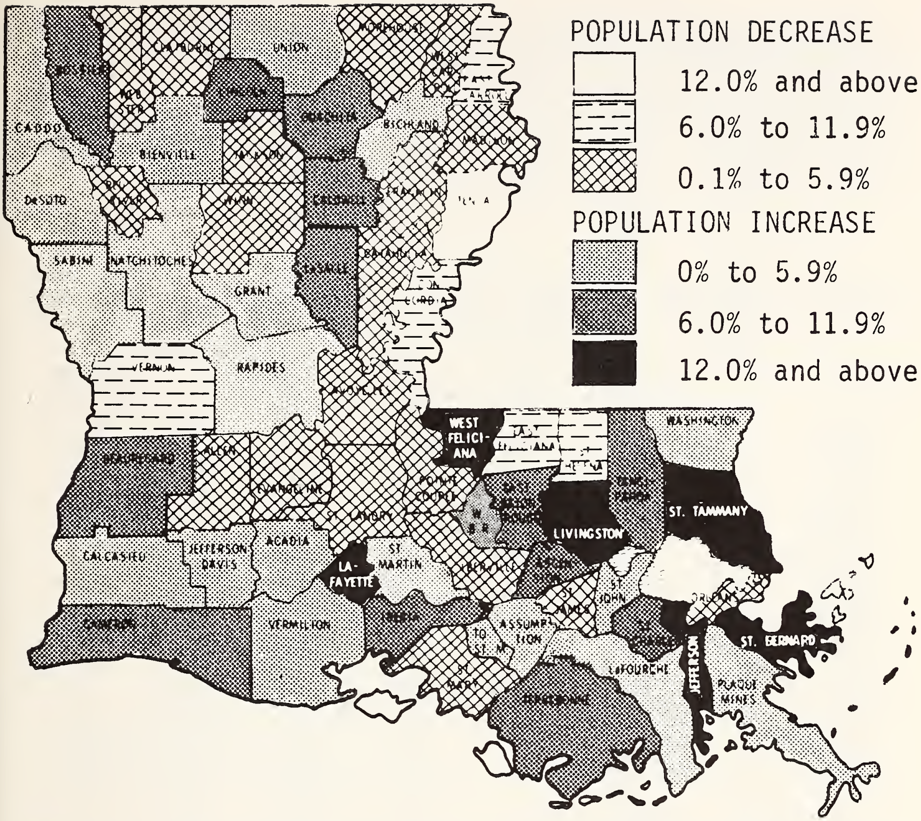

Figure 2. — The parishes of Louisiana: percent change in population, 1970-1975. (Source: Computed from data obtained from the U. S. Bureau of the Census, *Current Population Reports,* Series P-26, No. 75-18, March, 1976.)

still be said that, overall, parishes along the Louisiana-Mississippi border experienced a decrease in population (except Tangipahoa, Washington, and St. Tammany). It is precisely along this border that the previously mentioned parishes with high population losses (West Feliciana and Tensas) are located. Conversely, parishes along the Louisiana-Texas border and the Gulf Coast experienced population(except Vernon and St. Mary). All five of the metrolitan parishes with increases of more than 12 percent are located in the southern portion of the state.

There was no consistent pattern along Louisiana's northern border. In the north-central part of the state, a ring of parishes that experienced increases is found surrounding two parishes that lost population (Jackson and Winn). A block of parishes with decreasing populations — Allen, Evangeline, Avoyelles, St. Landry, Pointe Coupee, and Iberville — is found in the south-central part of the state.

The amount and rate of both natural increase and net migration for each parish during the 5-year period under analysis are shown in Table 12. The parishes are also ranked according to each of the two rates. None of the parishes experienced natural decrease; that is, none had a greater number of deaths than births. The lowest rate was that for Claiborne (0.9), while the highest was that for Bossier Parish (16.0).

Table 12.—The Parishes of Louisiana: Components of Population Change, 1970-1975

	Natural Increase			Net Migration		
Parish	Number	Rate	Rank[1]	Number	Rate	Rank[2]
Louisiana	183,225	9.6		–35,188	–0.97	
Acadia	2,512	9.2	26	–1,521	–2.92	33
Allen	797	7.3	37	–1,491	–7.17	52
Ascension	2,638	13.5	4	376	1.01	20
Assumption	1,068	10.3	19	–722	–3.67	37
Avoyelles	1,245	6.3	46	–1,496	–3.96	41
Beauregard	979	8.1	35	1,733	7.57	4
Bienville	228	2.7	63	348	2.17	15
Bossier	5,321	16.0	1	–1,324	–2.08	28
Caddo	10,735	8.9	31	–2,519	–1.09	23
Calcasieu	8,151	10.7	18	–3,066	–2.11	29
Caldwell	176	3.6	61	570	6.09	7
Cameron	393	9.1	28	313	3.82	9
Catahoula	375	6.1	50	–1,044	–8.87	56
Claiborne	79	0.9	64	–903	–5.30	45
Concordia	747	6.3	44	–2,225	–9.85	60
DeSoto	610	5.1	54	–574	–2.52	31
East Baton Rouge	17,693	11.8	11	8,540	2.99	11
East Carroll	648	9.6	23	–1,632	–12.67	62
East Feliciana	763	8.2	34	–1,920	–10.87	61
Evangeline	1,085	6.5	42	–1,217	–3.81	39
Franklin	875	7.0	40	–1,721	–7.19	53
Grant	364	5.1	56	265	1.94	16
Iberia	3,548	11.8	13	455	0.79	21
Iberville	1,417	8.8	32	–1,763	–5.73	47
Jackson	410	4.9	57	–473	–2.96	34
Jefferson	23,561	13.3	7	34,010	10.06	2
Jefferson Davis	1,338	8.6	33	–1,092	–3.69	38
Lafayette	7,778	13.3	6	5,879	5.27	8
Lafourche	4,237	11.7	14	–1,178	–1.71	25
LaSalle	355	5.1	55	850	6.39	6
Lincoln	1,221	6.9	41	1,079	3.19	10
Livingston	2,454	12.8	8	3,435	9.41	3
Madison	707	8.9	29	–1,372	–9.11	57
Morehouse	1,693	9.9	20	–2,256	–6.95	51
Natchitoches	1,184	6.4	43	–703	–2.00	27
Orleans	19,312	6.2	47	–48,483	–8.17	55
Ouachita	7,145	11.8	12	3,068	2.66	12
Plaquemines	1,976	14.9	3	–1,301	–5.16	44
Pointe Coupee	813	7.0	39	–1,215	–5.52	46
Rapides	5,694	9.2	25	–2,272	–1.92	26

(Continued)

Table 12.—(Continued)

Parish	Natural Increase			Net Migration		
	Number	Rate	Rank[1]	Number	Rate	Rank[2]
Red River	266	5.5	52	–292	–3.16	35
Richland	1,016	8.9	30	–990	–4.55	43
Sabine	545	5.6	51	317	1.70	18
St. Bernard	3,052	11.4	17	3,563	6.96	5
St. Charles	1,927	12.4	9	523	1.77	17
St. Helena	275	5.3	53	–912	–9.18	58
St. James	1,015	9.8	21	–1,148	–5.82	48
St. John the Baptist	1,516	12.1	10	–629	–2.64	32
St. Landry	4,071	9.6	22	–5,035	–6.27	49
St. Martin	1,994	11.7	15	–347	–1.07	22
St. Mary	4,282	13.4	5	–4,434	–7.30	54
St. Tammany	3,143	9.4	24	9,672	15.21	1
Tangipahoa	3,175	9.2	27	1,550	2.35	13
Tensas	208	4.1	60	–1,440	–14.80	63
Terrebonne	6,315	15.8	2	1,036	1.36	19
Union	423	4.4	58	430	2.33	14
Vermilion	1,648	7.3	38	–519	–1.20	24
Vernon	1,193	4.2	59	–5,187	–9.64	59
Washington	1,387	6.3	45	–1,374	–3.27	36
Webster	1,278	6.1	49	–1,617	–4.05	42
West Baton Rouge	1,029	11.6	16	–393	–2.33	30
West Carroll	523	7.6	36	–851	–6.53	50
West Feliciana	345	6.1	48	–1,906	–17.71	64
Winn	274	3.2	62	–643	–3.93	40

[1] Rank assigned according to the rate of natural increase, with the highest rate receiving to the rank of 1, and the lowest receiving the rank of 64.

[2] Rank assigned according to the rate of net migration, with the highest positive rate receiving the rank of 1, and the highest negative receiving the rank of 64.

Source: Compiled and computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports,* series P-26, No. 75-18, March, 1976; Office of the Public Health Statistics, 1974 Series, No. 4 and 1975 Series No. 2 and *Vital Statistics of Louisiana,* 1971, 1972 and 1973.

Geographic distribution of parish rates of natural increase are shown in Figure 3, with the intention of once again determining spatial patterns. Parishes with high rates of natural increase (more than 12 per 1,000) were found almost exclusively in the lower Mississippi Delta. The only exception was Bossier. Most of the 17 parishes with medium-high natural increase rates of 9.0 to 11.9 are also located in the southern portion of the state. Perhaps the relatively large proportion of Roman Catholics and persons of French culture in the southern parishes was a factor influencing these high rates. Of the 14 parishes with rates of natural increase categorized as low (less than 6 per 1,000), 13 are located north of Alexandria. St. Helena was the only parish in the southern half of the state with a rate below 5.9.

The last two columns in Table 12 indicate that two-thirds of the parishes experienced a loss of people, or a negative net migration. St. Tammany was the parish which, proportionately, gained the most through

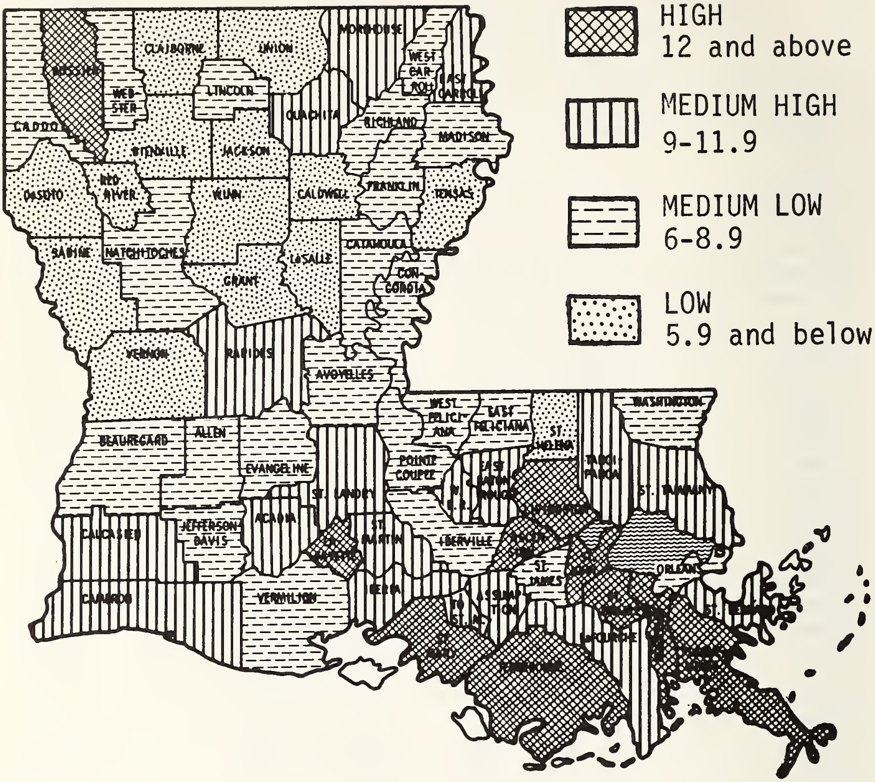

Figure 3. — The parishes of Louisiana: rates of natural increase, 1970-1975. (Source: Compiled and computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports,* Series P-26, No. 75-18, March, 1976; Office of Public Health Statistics, *Public Health Statistics,* 1974 Series, No. 4, and 1975 Series, No. 2, and *Vital Statistics of Louisiana*, 1971, 1972 and 1973.)

migration, while West Feliciana was ranked last, losing more than 17 percent of its 1970 population because of the severe imbalance between the numbers of outmigrants and inmigrants.

Figure 4 is the counterpart of Figure 3 for net migration. While a great proportion of the parishes along the northern and eastern borders of Louisiana were losing population through the exchange of migrants with other areas, no predominant pattern was found along the Texas border and along the Gulf Coast. The three parishes with the heaviest losses (East Carroll, Tensas, and West Feliciana) are all located along the Mississippi border; in fact, all parishes on that border experienced losses through migration except Tangipahoa and St. Tammany. The latter, of course, is a New Orleans SMSA parish.

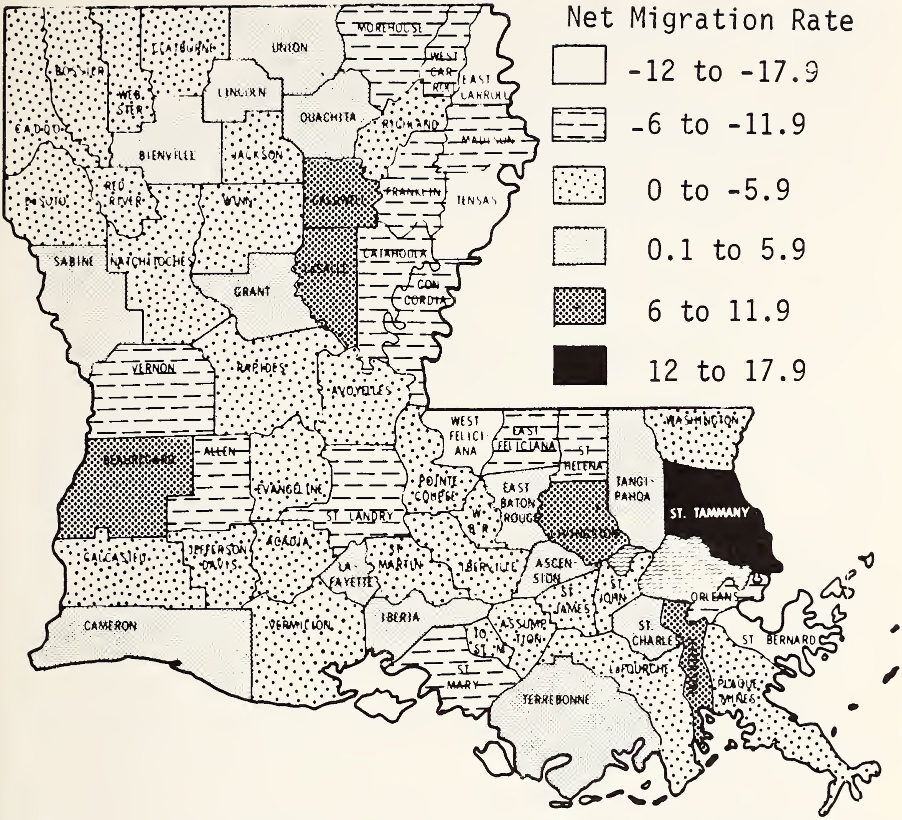

Figure 4. — The parishes of Louisiana: rates of net migration, 1970-1975. (Source: Compiled and computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports,* Series P-26, No. 75-18, March 1976; Office of Public Health Statistics, *Public Health Statistics,* 1974 Series, No. 4, and 1975 Series, No. 2, and *Vital Statistics of Louisiana,* 1971, 1972 and 1973.)

After analyzing separately population change and its components, it is worthwhile to examine them together. Perhaps some conclusions can be reached about the relative importance of natural increase and net migration in determining rates of change. Although all parishes that experienced positive net migration increased their populations between 1970 and 1975, it is not true that all parishes that increased their populations experienced positive net migration. In fact, there were 17 parishes that grew despite negative net migration. A majority of these are located in the lower Mississippi Delta, where natural increase was sufficiently high to offset losses due to migration. Perhaps the best way to summarize the relationship between the levels of natural increase, net migration, and population change is to say that a parish's rate of change was determined largely by the rate of net migration, with the levels of fertility and mortality acting primarily as mediating factors; that is, they had an effect only when the rate of natural increase was either fairly high or fairly low. In cases where the surplus of births over deaths was substantial, the parish was able to offset losses incurred through migration and grow, or, if it experienced positive net migration, the high rate of natural increase contributed to a rapid rate of growth. On the other hand, in parishes with fairly low levels of natural increases, negative net migration invariably meant that the population of the parish would decrease during the 5-year period.

Support for the argument that a parish's rate of growth is largely determined by the level of net migration can be found in their rank-orders assigned according to rates of change, natural increase, and net migration in Tables 11 and 12. Spearman's coefficient of rank-order correlation measures the degree of correspondence between two sets of ranks. The value of the coefficient ranges from 1.0 (perfect agreement of ranks) to −1.0 (perfect reversal of ranks). A coefficient of 0.0 indicates absolutely no correspondence between the two sets of ranks. The measure was applied here to test the degree of correspondence between two paired sets of ranks: (1) ranks according to percent change and ranks according to natural increase, and (2) ranks according to percent change and ranks according to net migration. In the first pair, the coefficient was 0.487, not a very strong association. But when ranks according to net migration were paired with ranks according to percent change, the coefficient was 0.961.

An examination of the situation in some of the parishes may illustrate the importance of net migration in determining rates of population change. Tensas and West Feliciana, the most extreme cases of population decrease in the state between 1970 and 1975, also experienced the highest negative net migration rates. Their low natural increase rates — 4.1 and 6.1 respectively — were unable to compensate for migration losses. Similarly, St. Tammany had a rate of natural increase slightly lower than the state's average, yet it was the parish with the highest positive net migration rate (15.21), and this resulted in the parish exhibiting the greatest increase in population in the entire state (20.1 percent).

Growth rates of the parishes from 1970 to 1975 were compared with their respective growth rates in the decade from 1960 to 1970. The annual growth rates for each parish during both time periods are shown in Table 13. The parishes have been grouped in the table according to the change that took place in their respective rates between the two time periods. There are six possible categories of change: (1) to a higher positive rate since 1970; (2) to a lower positive rate; (3) a change from negative to positive annual growth rate; (4) a change from positive to negative annual growth rate; (5) a lower negative rate; and (6) a higher negative rate since 1970.

The grouping with the greatest number of parishes is the second one, which represents a change to a lower positive rate since 1970. The state as a whole was characterized by such a trend, growing at a rate of 0.76 from 1970 to 1975, in comparison with a rate of 1.12 in the previous decade.

An examination of Table 13 shows that among parishes that had positive growth rates in the previous decade, 21 exhibited lower positive rates from 1970 to 1975, 13 switched to negative rates, and 11 grew faster than

Table 13.—The Parishes of Louisiana Grouped According to the Amount and Direction of Changes in the Annual Growth Rates Between 1960-1970 and 1970-1975

Parish	Annual Growth Rate	
	1960-1970	1970-1975
Louisiana	1.12	0.76
Higher positive AGR in 1970-75 than in 1960-70		
Beauregard	1.78	2.16
Bossier	1.14	1.17
Calcasieu	0.28	0.66
Caldwell	0.38	1.47
Grant	0.25	0.86
Iberia	1.06	1.29
LaSalle	0.22	1.67
Ouachita	1.27	1.63
Sabine	0.04	0.87
Tangipahoa	1.03	1.33
Union	0.46	0.87
Lower positive AGR in 1970-75 than in 1960-70		
Acadia	0.42	0.36
Ascension	2.88	1.50
Assumption	0.89	0.33
Caddo	1.01	0.67
Cameron	1.72	1.59
East Baton Rouge	2.17	1.69
Jefferson	4.94	3.04
Lafayette	2.81	2.22
Lafourche	2.21	0.83
Lincoln	1.71	1.26
Livington	3.07	2.89
Plaquemines	1.13	0.50
Rapides	0.59	0.55
St. Bernard	4.75	2.34
St. Charles	3.37	1.53
St. John	2.59	0.70
St. Martin	1.11	0.95
St. Tammany	5.11	3.56
Terrebonne	2.27	1.77
Vermilion	1.04	0.49
West Baton Rouge	1.32	0.71

(Continued)

in the 1960-1970 period. Among parishes that were losing population during the 1960's, seven have slowed their rate of population loss, six reversed the trend and started increasing, but six others lost, proportionately, even more persons than in the previous decade.

With the exceptions of Orleans and Webster, all metropolitan parishes

Table 13.—(Continued)

	Annual Growth Rate	
Parish	1960-1970	1970-1975
Change from negative to positive AGR between 1960-70 and 1970-75		
Bienville	-0.43	0.68
DeSoto	-0.63	0.03
Jefferson Davis	-0.09	0.16
Natchitoches	-0.12	0.26
Richland	-0.90	0.02
Washington	-0.47	0.0001
Change from positive to negative AGR between 1960-70 and 1970-75		
Allen	0.46	-0.64
Avoyelles	0.04	-0.13
Catahoula	0.30	-1.11
Concordia	0.99	-1.28
Evangeline	0.09	-0.08
Iberville	0.27	-0.22
Jackson	0.09	-0.08
St. Helena	0.82	-1.25
St. James	0.72	-0.13
St. Mary	2.21	-0.05
Vernon	11.39	-1.46
Webster	0.06	-0.16
Winn	0.21	-0.43
Lower negative AGR in 1970-75 than in 1960-70		
Claiborne	-1.30	-0.94
East Feliciana	-1.34	-1.28
Franklin	-0.85	-0.68
Madison	-0.87	-0.86
Morehouse	-0.38	-0.33
Red River	-0.78	-0.05
West Carroll	-0.84	-0.49
Higher negative AGR in 1970-75 than in 1960-70		
East Carroll	-1.13	-1.50
Orleans	-0.56	-0.96
Pointe Coupe	-0.22	-0.35
St. Landry	-0.14	-0.23
Tensas	-1.91	-2.55
West Feliciana	-1.40	-2.94

Source: Compiled and computed from data obtained from the U.S. Bureau of the Census, *Current Population Reports,* Series P-26, No. 75-18, March 1976, and *U.S. Census of Population,* 1960, PC (1)-A20, Louisiana.

grew during both the 1960-1970 and 1970-1975 periods. Most of the metro parishes, however, were in the category of lower positive rates in the latter period. Except for Sabine, all parishes that have experienced higher growth rates since 1970 are either metropolitan or adjacent nonmetropolitan. An overwhelming majority of parishes that lost population during both periods were either less urbanized or totally rural nonmetro parishes. The six parishes that went from negative to positive rates were all adjacent nonmetropolitan parishes. This type of change was the only one that did not contain any totally rural parishes. As for the group of 13 parishes that went from population growth to population decline, the majority were less urbanized nonmetro parishes.

Vernon stands out as the parish that exhibited the greatest contrast in its annual growth rates for the two time periods. The difference between its 1960-1970 and 1970-1975 rates was 12.85. The difference between the two rates for the state as a whole was only 0.36. Although Vernon's rate of natural increase has not changed significantly since 1970, the change in net migration has been phenomenal. During the 1960's, when Fort Polk was reactivated, the parish was gaining an average of about 3,331 persons a year. Since 1970, however, it has been losing about 988 persons annually. Consequently, in the latter period the parish declined by an annual rate of −1.46, in contrast to its 1960-1970 rate of +11.39

SUMMARY OF THE FINDINGS

1. Despite losing population through migration from 1970 to 1975, the population of Louisiana during that period increased 4.1 percent. This growth was due to a surplus of births over deaths, which was more than sufficient to offset migration losses.

2. Since 1970, contrary to the widely publicized national trend, metropolitan areas in Louisiana have grown at a faster rate than nonmetropolitan areas. Whereas the metro areas as a whole recorded relatively small gains through migration, the nonmetro areas, especially those not adjacent to metro parishes, experienced heavy migration losses. As for natural increase, metro parishes gained proportionately more population through excess of births over deaths than did the nonmetro parishes as a whole.

3. Within the metro classification, the medium and smaller metro areas since 1970 have exhibited higher growth rates than the one greater metro area in the state (the New Orleans SMSA). The medium and smaller metro areas experienced positive net migration and relatively high rates of natural increase. In contrast, the New Orleans SMSA as a whole lost population through migration and had relatively low rates of natural increase.

4. In the nonmetro areas, the population in parishes adjacent to metro areas in general has grown since 1970 at a faster rate than the population

of nonadjacent parishes. In a pattern once again contrary to the national trend, the most urbanized nonmetro parishes (both adjacent and nonadjacent) experienced the greatest increase of all nonmetro areas. The finding that totally rural nonmetro parishes in Louisiana continued to be areas of either population loss or very slow growth consitutes another deviation from the national trend. A look at the components of change proved useful: among the nonmetro parishes, the most urbanized one exhibited the highest rates of natural increase, whereas the totally rural parishes had the lowest rates. In terms of net migration, losses incurred by the more urbanized nonmetro parishes were not as significant, proportionately, as losses experienced by the totally rural parishes. The latter continued to be the greatest losers in net migration.

5. In comparison with the period from 1960 to 1970, all residence categories in Louisiana grew at a slower rate from 1970 to 1975. The nonmetro-nonadjacent parishes stand out as having populations with the greatest decline in rates of change between the two periods. Due to an overall reduction in the birth rate since the 1960's, natural increase in all residence classes has declined, with the less urbanized and totally rural parishes showing the greatest decrease. As for net migration, metro areas in general began to gain population in 1970 after a decade of negative net migration. This pattern was particularly the case in the medium and smaller metro areas. The greater metro area deviated from this pattern: its core parish continued the previous trend of losing population and the fringe parishes began to level off in the volume of positive net migration. The net migration trends in the nonmetro areas were much more uniform: all subcategories continued into the 1970's a tradition of losing population that had prevailed during the previous decade.

6. Overall, the parishes along the eastern border of the state tended to have smaller populations in 1975 as compared with 1970, whereas parishes along the western border and the coast tended to grow during the 5-year period. The parishes with the highest rates of negative net migration are located along the Mississippi border. Parishes with high rates of natural increase are likely to be found in the southern portion of the state, while parishes with low rates of natural increase are primarily northern parishes. The level of net migration has undoubtedly been much more influential than natural increase in determining rates of change in the populations of the parishes of Louisiana from 1970 to 1975.

7. A comparison of parish growth rates from 1970 to 1975 with their respective growth rates during the decade of the 1960's showed that among the 45 parishes that had grown in population in that previous decade, one-fourth began experiencing reductions in their total populations. The rest were able to keep growing in the 1970's, but mostly at a slower rate than during the 1960's. As for the 19 parishes that were losing population, two-thirds of them continued to lose population from 1970 to 1975, while the rest started growing at a fairly slow rate.

CONCLUSIONS

It is hardly necessary to repeat here that Louisiana is not following the national trend toward population growth in nonmetropolitan America. The overwhelming majority of nonmetro parishes in the state are either losing population or growing slowly, and continue to lose persons in the exchange of population with other areas.

Nonadjacent and rural parishes are the principal losers in the nonmetro category, and it does not appear that this tendency is about to be reversed. On the contrary, these parishes were losing more population and growing at an even slower rate during 1970 to 1975 than during the 1960's. On the other hand, metropolitan areas continue to grow faster than nonmetro areas; in fact, during the period from 1970 to 1975, metro areas gained population through migration, reversing the trend that predominated during the 1960's of losing population as a result of migration. There were significant differences, however, within the metro category. Orleans Parish exhibited trends typical of "central city" or "core" areas of large U.S. cities; it has been losing population during the past 15 years through heavy outmigration. In contrast, the fringe parishes of the New Orleans SMSA are the fastest growing areas in the state. Because of migration losses the core parish is incurring, however, the growth rate of the New Orleans SMSA as a whole has leveled off and it is not gaining as much population through migration as its did in the 1960's.

What emerges as a crucial consideration in understanding the changes in the population of Louisiana since 1970 is the role of medium-sized cities, specifically Lafayette, Baton Rouge, and Monroe. These three areas, particularly Lafayette, have registered tremendous gains in population since 1970 as a result of both high net migration and natural increase. This is consistent with Beale's (1976, p. 956) observation that small to medium-sized metro areas have increased net inmigration during the 1970's and that it is only in the large metro areas that we find declining population growth. However, unlike Beale's other findings about the national population, the tendency toward heavier inmigration and higher growth rates exhibited by these medium metro areas does not extend, in Louisiana, to nonmetro areas, as it does in the rest of the nation.

One possible explanation for the observed trends is that nonmetro areas in Louisiana have not yet "bottomed out" in terms of their contributions to the growth of metro areas and that it is the medium and smaller metro areas, particularly those located along a north-south axis through the center of the state, that are increasingly becoming the principal beneficiaries of those contributions.

Obviously, it is not entirely valid to test the applicability of findings derived from a study of the national population to the situation in one particular state, primarily because a state is not a fairly enclosed and inclusive migration unit, as is a national population. Nevertheless, the findings by Beale and others have been used here only as a guide in the examination of residential differentials in rates of change within the state of Louisiana. This study provides citizens and officials with a picture of the trends in their state and how these compare with highly-publicized national patterns. It also provides the demographic explanations for these trends. Future research will have to consider those essential demographic explanations and also examine factors in the social and economic organization of the state that are associated with the observed rates of population change. Why do nonmetro areas in Louisiana continue to contribute a large number of migrants to other areas? What are the factors behind the high rates of net inmigration and natural increase of medium and small metro areas? Perhaps, unlike the national situation (Beale, 1976, p. 975), the gap between rural and metro areas of Louisiana in the availability and quality of services and in the conveniences of living has not been reduced to the point where living in rural areas is as satisfying as living in metro areas. In other words, it is possible that it still makes quite a bit of difference, in terms of services and other amenities of life, as to whether one resides in rural or metropolitan Louisiana. Another possible avenue of investigation would be to determine whether small and medium metro areas of Louisiana have recently acquired or intensified their economic functions so as to create a rise in employment opportunities. It is undoubtedly true, for example, that offshore oil and gas development has been largely responsible for the rapid growth of Lafayette.

REFERENCES

Beale, Calvin L. *The Revival of Population Growth in Nonmetropolitan America.* USDA ERS-605, June 1975.

Beale, Calvin L. "A Futher Look at Nonmetropolitan Populaton Growth Since 1970," *American Journal of Agricultural Economics,* Vol. 58, No. 5, December 1976, pp. 953-958.

Bowles, Gladys K., and Everett S. Lee. *Net Migration of the Population, 1960-1970, by Age, Sex and Color,* Part 5. USDA ERS, University of Georgia Printing Department. Athens, Georgia, 1975.

Hines, Fred K., David L. Brown, and John M. Zimmer. *Social and Economic Characteristics of the Population in Metro and Nonmetro Counties, 1970.* USDA ERS Agr. Economic Rep. No. 272, March 1975.

Morrison. Peter A. and Judith P. Wheeler. "Rural Renaissance in America?" *Population Bulletin,* Vol. 31. No. 3, Oct. 1976.

Office of Public Health Statistics. *Vital Statistics of Louisiana,* 1971. 1972 and 1973. Louisiana Health and Human Resource Administration.

Paterson, Karen W. and Alvin L. Bertrand. *Louisiana's Human Resources, Part V, Population Changes by Parishes and Incorporated Places 1950-1970.* Bulletin No. 661. Louisiana State University. Agricultural Experiment Station. 1972.

Shryroc, Henry S., Jacob S. Siegel and Associates. *The Methods and Materials of Demography,* U. S. Bureau of the Census. Washington. D. C. 1973.

Tucker, C. Jack. "Changing Patterns of Migration Between Metropolitan and Nonmetropolitan Areas in the United States: Recent Evidence," *Demography,* Vol. 13, No. 4, November 1976, pp. 435-443.

U. S. Bureau of the Census. *Current Population Reports*, P-26, No. 75-18. "Estimates of the Population of Louisiana Parishes and Metropolitan Areas: July 1, 1974 and 1975." March. 1976.

U. S. Bureau of the Census. *U. S. Census of Population: 1960. Number of Inhabitants, Louisiana* PC (1)-20. Government Printing Office, Washington, D.C., 1961.

Wardwell. John M. "Reversal of Metropolitan and Nonmetropolitan Growth Patterns: Equilibrium or Change?" Paper presented at the annual meeting of the Population Association of America, Montreal, 28 April-1 May 1976.

Bulletin No. 706 October 197

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factors affecting the purchase and use of SWEET POTATOES

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Preface

This report is intended to provide an insight into factors affecting the purchase and use of sweet potatoes. It contains information on the extent and frequency of use of sweet potatoes, why some consumers never purchase the product, and why many purchase infrequently. It also contains information on consumer preferences regarding various quality factors, and on consumer views regarding what should be done to make the product more acceptable.

The findings are from a consumer survey in five cities of the northeastern United States where per capita consumption of sweet potatoes is low relative to other market areas. Members of the industry, from farmer to retailer, should find the results useful as a guide to effective marketing, promotion, and merchandising of sweet potatoes. The results should be of particular interest to research workers in developing sweet potato varieties and products tailored to consumer requirements and preferences.

Acknowledgments

This study was supported largely by state and federal funds under Regional Project S-101. In addition, it was supported by supplemental grants from the Louisiana Sweet Potato Association and from the Sweet Potato Council of the United States.

The author wishes to acknowledge the following for their roles in the study:

Dr. John Nichols and Dr. Randall Stelly, Texas Agricultural Experiment Station, who participated in planning the consumer survey and developing the questionnaire, and provided assistance with briefing interviewers for the initial phase of the survey; Ms. Jane Ottenhouse, Consumer and Marketing Specialist with the Louisiana Cooperative Extension Service, who assisted in briefing interviewers and provided informational material for distribution to interviewees; Dr. Gayle Ammerman, Mississippi Agricultural Experiment Station, and Dr. Roy Constantin, Dr. Harrell Hammett, and Dr. Teme Hernandez, Louisiana Agricultural Experiment Station, who provided photographs and professional advice for designing visuals used in the survey to illustrate certain sweet potato quality factors; Mrs. Ruth Thompson and Mrs. Mary Thrasher, artists with the Louisiana Cooperative Extension Service, for developing visuals used in the study; Dr. H. Rouse Caffey, Associate Director of the Louisiana Agricultural Experiment Station, for his support and counsel during the study, and members of the Technical Committee, S-101, for reviewing the manuscript.

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[1] Resigned April 1977.

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Factors Affecting the Purchase and Use of Sweet Potatoes

JERRY M. LAW*

Introduction

This study of consumer attitudes toward sweet potatoes was undertaken to provide guidelines for programs of mutual benefit to the industry and the consumer. Information about factors affecting the purchase and use of sweet potatoes is needed by the industry as a basis for more effective marketing, promotion, and merchandising activities. It is also needed as a guideline for research workers striving to develop sweet potato varieties and products tailored to requirements and preferences of the consumer. The study was initiated in recognition of these needs and out of concern about a long time decline in per capita consumption of sweet potatoes in the United States.

The findings are based upon information obtained from 2,525 households in five cities of the northeastern United States during 1975. The households in the sample[1] were selected at random from the metropolitan areas of Milwaukee (Wisconsin), Cincinnati (Ohio), Pittsburgh (Pennsylvania), Rochester (New York), and Boston (Massachusetts). Information was obtained by personal interview in the households of consumers. For purposes of the study a household was considered to be any occupied dwelling with cooking facilities. The interview was conducted with the individual who usually decided which food items were to be purchased for the household.

Why Some Consumers Don't Buy Sweet Potatoes

Consumers were asked if they had prepared and served sweet potatoes in the home at least once during the year preceding the time of the interview. For purposes of the study they were classified as users or nonusers, depending upon whether they responded "yes" or "no" to the question.

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[1] The sampling procedure and sample reliability are discussed in more detail in Appendix A.

Accordingly, approximately 17 percent of the consumers interviewed were nonusers (Table 1). Nonusers were asked for reasons why they had not prepared and served sweet potatoes. The majority (52.5 percent) indicated no specific reason,[2] but said they just did not care for sweet potatoes. Main reasons given by other nonusers included dislike of sweet taste, trouble to prepare, and high calorie content. Less than 3 percent of the nonusers gave reasons having to do with undesirable quality factors. (Table 2).

Table 1.— Proportion of consumers who were users and nonusers of sweet potatoes

Item	Households	
	Number	Percent
Users	2,091	82.8
Nonusers	434	17.2
All applicable	2,525	100.0

Table 2. — Reasons given by consumers for not using sweet potatoes

Reasons for not using sweet potatoes	Households	
	Number	Percent
Just don't care for sweet potatoes	228	52.5
Don't like sweet taste	75	17.3
Too much trouble to prepare	58	13.4
Diet doesn't permit	22	5.0
Too expensive	16	3.7
Mushy, mealy, or gummy	12	2.8
Don't cook at home	10	2.3
No response	13	3.0
All applicable	434	100.0

Except for demographic data presented in the Appendixes, no additional information was requested of nonusers. The remainder of the text is about those consumers who do use sweet potatoes.

Frequency of Sweet Potato Purchases

Approximately 83 percent of the consumers indicated that they had prepared and served sweet potatoes in the home at least once during the year preceding the interview; however, most were infrequent users. Almost 72 percent of the users reported purchasing sweet potatoes not more than six times during the year. The most often reported frequency was twice during the year (Table 3). Purchases ranging from seven to 12 times during the year were indicated by about 18 percent of the users. A few

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[2] Interviewers attempted to get specific reasons by probing.

Table 3. — Frequency with which sweet potatoes were purchased by consumers

Times purchased during year	Households Number	Households Percent
1	241	11.5
2	370	17.7
3	269	12.9
4	254	12.1
5	140	6.7
6	222	10.6
7	20	1.0
8	37	1.8
9	7	0.3
10	59	2.8
11	2	0.1
12	249	11.9
13 - 24	133	6.4
25 - 48	55	2.6
49 - over	29	1.4
No response	4	0.2
All applicable	2,091	100.0

consumers (1.4 percent of the users) reported purchasing sweet potatoes about once per week or more on the average.

Those who indicated purchasing sweet potatoes less than once per month (78 percent of the users) were asked for reasons why they did not purchase more often. The response for more than one-third of the group was that some members of the family did not like sweet potatoes (Table 4). Other relatively frequent reasons were "sweet potatoes are considered a seasonal or special occasion dish," "other foods are preferred except on occasion," "too high in calories," and "generally don't think about sweet potatoes."

Table 4. — Reasons given by consumers who purchase sweet potatoes less often than once per month

Reason for infrequent purchases	Households Number	Households Percent
Some members of family don't like sweet potatoes	576	35.5
Consider it a seasonal or special occasion dish	246	15.2
Prefer other foods	190	11.7
Too high in calories	152	9.4
Don't think about them	140	8.6
Too expensive	67	4.1
Not always available	52	3.2
Too much trouble to prepare	32	2.0
Miscellaneous	29	1.8
Don't know	74	4.6
No response	63	3.9
All applicable	1,621	100.0

Sweet potatoes reflect a special occasion or holiday image for the majority of consumers. Sixty percent of the users said they served sweet potatoes only on certain occasions. The occasions were mostly Thanksgiving, Christmas, and Easter holidays, and when having guests in the home (Table 5).

Table 5. — When sweet potatoes are served by consumers who use the product only on certain occasions

	Households	
Occasion sweet potatoes served	Number	Percent
Holidays and when we have company	396	31.5
Thanksgiving and Christmas	386	30.7
Thanksgiving	197	15.6
Thanksgiving, Christmas, and Easter	78	6.2
Thanksgiving and Easter	38	3.0
Other[1]	152	12.1
No response	11	0.9
All applicable	1,258	100.0

[1] Includes various combinations of the above occasions.

Almost half of the consumers also indicated they purchased sweet potatoes only during certain months. However, the months indicated by most were those which covered the major holiday periods associated with peak sweet potato consumption. November and/or December were indicated by the majority (Appendix Table 10). Many consumers indicated they purchased only during the winter months, or during November through March. If sweet potatoes were of higher quality during the late fall and winter months, one might suspect that this influenced seasonal consumption. However, there was no evident concern on the part of the consumer about possible variations in sweet potato quality at different times of the year. The overriding factor influencing the time of year sweet potatoes were purchased appeared to be the image that this is a cool-weather-holiday food item.

Consumer Buying Habits

Forms of Sweet Potatoes Purchased. — Consumers were asked what form of sweet potatoes they usually buy. Sixty-three percent said they usually buy fresh sweet potatoes. Almost 37 percent said they usually purchase canned sweet potatoes. The remaining few indicated frozen sweet potatoes as the usual form purchased[3] (Table 6).

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[3] The proportion of consumers indicating forms usually purchased does not necessarily equal the proportionate amount of each form that is consumed.

When asked what other forms they purchase, almost half of the respondents indicated none. Canned sweet potatoes were the predominant choice of those who bought other forms in addition to their usual purchase (Table 6).

Purchases by Weight vs. Count. — Approximately two-thirds of the consumers said they purchased fresh sweet potatoes by count. When asked how many they usually purchase at a time, the more typical responses were in the range of three to six sweet potatoes (Table 7). Most of the remaining one-third who purchased by weight indicated usual purchases ranging from 1 to 5 pounds, but the more typical weights were 2 and 3 pounds (Table 7).

Factors in Shopping for Fresh Sweet Potatoes. — Consumers were asked to rank the relative importance of price, color, size, and shape as factors taken into consideration when shopping for fresh sweet potatoes. The most important consideration for over 40 percent of the respondents was the size of the sweet potato (Table 8). An additional one-fourth of the

Table 6. — Proportion of consumers who purchase specified forms of sweet potatoes

	Usual purchase		Purchase in addition to usual	
	Households		Households	
Form purchased	Number	Percent	Number	Percent
Fresh	1,317	63.0	284	13.6
Canned whole	573	27.4	491	23.5
Canned cut	172	8.2	201	9.6
Frozen	25	1.2	39	1.8
None			980	46.9
No response	4	0.2	96	4.6
All applicable	2,091	100.0	2,091	100.0

Table 7. — Proportion of consumers who purchase specified amounts of fresh sweet potatoes at one time by count or by weight

	Purchase by count		Purchase by weight	
	Households		Households	
Pounds or number purchased	Number	Percent	Number	Percent
1	10	0.9	44	8.7
2	94	8.6	174	34.3
3	150	13.7	143	28.1
4	331	30.3	53	10.4
5	145	13.3	58	11.4
6	230	21.1	9	1.8
7	20	1.8	1	0.2
8	60	5.5	1	0.2
9 or more	47	4.3	25	4.9
No response	6	0.5	0	0.0
All applicable	1,093	100.0	508	100.0

Table 8. — Relative importance of price, color, size, and shape as factors considered by consumers when shopping for fresh sweet potatoes

Factors considered	Most important consideration		2nd most important consideration		3rd most important consideration	
	Households		Households		Households	
	Number	Percent	Number	Percent	Number	Percent
Size	664	41.5	548	34.2	270	16.9
Color	410	25.6	420	26.2	457	28.5
Price	347	21.7	227	14.2	323	20.2
Shape	180	11.2	406	25.4	551	34.4
Total	1,601	100.0	1,601	100.0	1,601	100.0

respondents considered external color as the most important consideration. About one-fifth considered price first, but about an equal number listed price as the third most important consideration. Sweet potato shape appeared to be of least concern among the four factors in shopping for fresh sweet potatoes.

Storage of Fresh Sweet Potatoes

When asked where they stored fresh sweet potatoes, over 42 percent said the refrigerator (Table 9). Evidently, many consumers are unaware that this procedure is not recommended. Twenty-seven percent stored fresh sweet potatoes some place within the main part of the house, such as the kitchen cabinet, pantry, or vegetable bin. Areas used by others included the storage cellar, basement, or garage.

Relatively few consumers indicated they stored sweet potatoes for more than 2 weeks. The more typical responses were "up to 3 days" and "up to 1 week" (Table 10). When asked if they had any problems with sweet potatoes going bad in storage, almost 17 percent responded "yes."

Table 9. — Place used by consumers for storing fresh sweet potatoes

Storage place	Households	
	Number	Percent
Refrigerator	677	42.3
Vegetable bin, kitchen cabinet, pantry	432	27.0
Storage cellar, basement, garage	345	21.5
None (use as purchased)	136	8.5
No response	11	0.7
All applicable	1,601	100.0

Table 10. — Length of time sweet potatoes are usually stored by consumers

Usual storage period	Households Number	 Percent
Up to 3 days	569	38.8
Up to 1 week	568	38.8
Up to 2 weeks	202	13.8
Up to 3 weeks	47	3.2
Up to 4 weeks	29	2.0
More than 4 weeks	33	2.2
No response	17	1.2
All applicable	1,465	100.0

How Consumers Use Sweet Potatoes

Usual Method of Preparation. — The vast majority (83 percent) of users said they usually prepared sweet potatoes in the candied or baked form, with candied being slightly more popular. Usual ways indicated by others, in order of importance, were boiled, cooked in a casserole, and fried. Some, apparently referring to ready-prepared sweet potatoes, indicated heat and serve (Table 11).

Use with Special Dishes. — More than 65 percent of the respondents indicated that they normally serve sweet potatoes with special dishes. When asked what special dish(es), the more typical responses, in order of importance, were ''with ham or turkey,'' ''with turkey or chicken,'' and ''with ham or other pork meat'' (Table 12).

Use as Substitute for Other Dishes. — About 45 percent of the respondents said that when they serve sweet potatoes, the dish is considered as a substitute for other dishes they might have served. When asked to indicate the dishes for which sweet potatoes were substituted, approximately 87 percent specified Irish potatoes. Some used sweet potatoes as a substitute for other starchy foods and some for a yellow vegetable (Table 13).

Table 11. — Ways consumers usually use or prepare sweet potatoes

Way used or prepared	Households Number	 Percent
Candied	760	36.3
Baked	665	31.8
Candied or baked	318	15.2
Boiled	202	9.7
Cooked in a casserole	44	2.1
Fried	39	1.9
Heat and serve	37	1.8
No response	26	1.2
All applicable	2,091	100.0

Table 12. — Special dishes with which sweet potatoes are normally served by consumers

Special dish	Households Number	Households Percent
With ham or turkey	442	31.7
With turkey or chicken	399	28.7
With ham or other pork meat	294	21.1
With ham or turkey or chicken	125	9.0
With pork or poultry or beef	92	6.6
With beef	14	1.0
No response	26	1.9
All applicable	1,392	100.0

Table 13. — Dishes for which sweet potatoes are considered a substitute by consumers

Dish	Households Number	Households Percent
Irish potatoes	800	86.9
Other starchy dishes	93	7.9
A yellow vegetable	29	3.8
No response	8	1.4
All applicable	930	100.0

Consumer Reaction to Fresh Sweet Potatoes

Respondents who indicated that they bought fresh sweet potatoes were asked to consider the size, shape, external color, and internal color of fresh sweet potatoes they find available. They were asked to indicate whether they were satisfied or dissatisfied with respect to each characteristic. The responses of those who indicated they were satisfied are summarized as follows:

Fresh Sweet Potatoes

Quality factor	Percent of respondents satisfied
Size	84.2
Shape	91.8
External color	94.2
Internal color	95.3

Consumers who indicated they were not satisfied with a particular characteristic were asked to give reasons for their dissatisfaction. The results are discussed below.

Size. — More than 15 percent of the respondents expressed dissatisfaction with the size of sweet potatoes available. When asked reasons for dissatisfaction, more than half indicated that sizes were not uniform enough. About one-fourth thought sizes were too large, and 14 percent felt sizes were generally too small (Table 14).

Table 14. — Reasons for consumer dissatisfaction with the size of sweet potatoes they find available

Reason for dissatisfaction	Households Number	Households Percent
Not uniform enough	132	53.9
Too large	62	25.3
Too small	34	13.9
No response	17	6.9
All applicable	245	100.0

Shape. — About 8 percent were dissatisfied with the shape of fresh sweet potatoes available to them. As with size, the main reason for dissatisfaction was lack of uniformity. Other reasons given most frequently were "too long" and "misshapen or twisted" (Table 15).

Table 15. — Reasons for consumer dissatisfaction with the shape of sweet potatoes they find available

Reason for dissatisfaction	Households Number	Households Percent
Not uniform enough	42	33.9
Too long	34	27.4
Misshapen or twisted	27	21.8
Too round	9	7.2
No response	12	9.7
All applicable	124	100.0

External Color. — Slightly more than 5 percent of the consumers who bought fresh sweet potatoes were dissatisfied with the external color of the product. Reasons mentioned most often were "black spots," "prefer whiter color," "prefer redder color," and "dull, drabby" (Table 16).

Internal Color. — Fewer people (about 4 percent) were dissatisfied with internal color than with the other visual characteristics of sweet potatoes. Main reasons given by those expressing dissatisfaction with internal color were "not orange enough," "not light enough," and "sometimes greenish color" (Table 17).

Table 16. — Reasons for consumer dissatisfaction with the external color of fresh sweet potatoes they find available

Reason for dissatisfaction	Households Number	Households Percent
Black spots	26	31.3
Prefer whiter color	15	18.1
Prefer redder color	14	16.9
Dull, drabby	10	12.1
Mottled, scurfy	4	4.8
Artificial color	4	4.8
No response	10	12.1
All applicable	83	100.0

Table 17. — Reasons for consumer dissatisfaction with the internal color of fresh sweet potatoes they find available

Reason for dissatisfaction	Households Number	Households Percent
Not orange enough	23	34.9
Not light enough	14	21.2
Sometimes greenish color	9	13.6
Mottled, dark spots	1	1.5
No response	19	28.8
All applicable	66	100.0

Respondents were also asked to rate the baking quality, texture, flavor, and overall quality of the fresh sweet potatoes they had been buying. The ratings were on a scale of 1 to 9, with 1 being desirable and 9 being undesirable. A large majority indicated favorable ratings (i.e., 1, 2, 3, or 4) for each of the three quality factors as follows:

Fresh Sweet Potatoes

Quality factor	Percent of respondents rating favorably
Flavor	89.2
Texture	83.2
Baking quality	78.8

Evaluations of flavor were concentrated heaviest on ratings of 1 and 2. Baking quality and texture were concentrated more on ratings of 2 and 3 (Appendix Tables 13, 14, and 15).

The overall quality of fresh sweet potatoes was rated favorably by more than 87 percent of the respondents, with 76 percent of them giving the product a rating of 3 or higher (Table 18). The overall quality of fresh sweet potatoes was rated from 6 to 9, or unfavorable, by about 4 percent of the respondents. Main reasons given for unfavorable ratings were "coarse and stringy," "poor flavor," "not as good as the old type," and "hard spots" (Table 19).

Table 18. — Consumer rating of the overall quality of fresh sweet potatoes

	Households	
Rating[1]	Number	Percent
1	410	25.6
2	419	26.2
3	388	24.2
4	186	11.6
5	135	8.4
6	26	1.6
7	14	0.9
8	11	0.7
9	6	0.4
No response	6	0.4
All applicable	1,601	100.0

[1] Based on a scale of 1 to 9, with 1 = desirable, 9 = undesirable.

Table 19. — Reasons given by consumers who gave unfavorable ratings to the overall quality of fresh sweet potatoes

	Households	
Reason for unfavorable rating	Number	Percent
Coarse and stringy	30	52.6
Poor flavor	11	19.3
Not as good as old type	8	14.1
Hard spots	6	10.5
Too dry	2	3.5
All applicable	57	100.0

Consumer Reaction to Processed Sweet Potatoes

Consumers who indicated using processed sweet potatoes were asked to rate the color, texture, and flavor of the processed product they had been buying. They also were asked to rate the overall quality of each processed form (canned or frozen). As with fresh sweet potatoes, all ratings were on a scale of 1 to 9, with 1 being desirable and 9 being undesirable.

A majority of the respondents gave favorable ratings (1 to 4 on the scale) to the various quality factors of processed sweet potatoes as follows:

Processed Sweet Potatoes

Quality factor	Percent of Respondents rating favorably
Color	74.7
Flavor	67.1
Texture	64.2

The proportion of users giving favorable ratings was generally lower than in the case of fresh sweet potatoes.

The overall quality of canned sweet potatoes was rated 1 to 4, or favorably, by 73 percent of the users. Approximately 10 percent rated the canned product from 6 to 9 (Table 20). Principal reasons given for unfavorable ratings were "overcooked, soggy," "bland," "coarse and stringy," and "off color" (Table 21).

Relatively few (64) of the respondents indicated using frozen sweet potatoes. Seventy-eight percent of the users rated the overall quality of the product from 1 to 4, or favorably. However, about 16 percent gave the

Table 20. — Consumer rating of the overall quality of canned sweet potatoes

Rating[1]	Households	
	Number	Percent
1	246	17.1
2	319	22.2
3	277	19.2
4	206	14.3
5	229	15.9
6	61	4.2
7	40	2.8
8	23	1.6
9	18	1.3
No response	20	1.4
All applicable	1,439	100.0

[1] Based on a scale of 1 to 9, with 1 = desirable, 9 = undesirable.

Table 21. — Reasons given by consumers who gave unfavorable ratings to the overall quality of canned sweet potatoes

Reason for unfavorable rating	Households	
	Number	Percent
Overcooked, soggy	52	36.6
Bland	38	26.8
Coarse and stringy	34	23.9
Off color	15	10.6
Poor quality	3	2.1
All applicable	142	100.0

frozen product an unfavorable rating (Appendix Table 19). Consumers who gave the product an unfavorable rating felt it was "tasteless," "too sweet," or "poor quality" (Appendix Table 20).

Consumer Reaction to Sweet Potatoes Consumed in Public Eating Places

Approximately 29 percent (613) of the users indicated they had consumed sweet potatoes in a public eating place, such as a restaurant or cafeteria. These respondents were asked whether they were satisfied with the sweet potatoes served. The majority said "yes," but 22 percent (135) said they were not satisfied (Appendix Table 21). The most frequent reason for dissatisfaction was that the sweet potatoes were tasteless or not seasoned. Other frequent reasons were that the sweet potatoes served were "watery and mushy," "not appealing," "hard and dry," and "too sweet" (Appendix Table 22).

Consumer Preferences Concerning Sweet Potatoes

Consumers were asked to indicate what they liked most about sweet potatoes, generally. A majority (62 percent) of the respondents indicated "sweet taste" as the thing they liked most. Other responses given frequently were that sweet potatoes "complement certain main dishes," and they are "a change from Irish potatoes" (Table 22).

Consumers also were asked to indicate what they disliked most about sweet potatoes. More than half (53 percent) indicated "nothing in particular." Specific dislikes mentioned most frequently by other consumers were "sometimes stringy," "high in calories," "sweet taste," and "difficult to prepare" (Table 23). High price was listed as a dislike; however, not many of the consumers indicated that price was a major concern.

Table 22. — Things consumers indicated they like most about sweet potatoes

	Households	
Like most about sweet potatoes	Number	Percent
Sweet taste	1,297	62.0
Complements certain main dishes	205	9.8
A change from Irish potatoes	198	9.5
Easy to prepare	60	2.9
Color	58	2.8
Nothing	43	2.0
Can be fixed a variety of ways	42	2.0
A change from other vegetables	41	2.0
A good holiday treat	38	1.8
Nutritional value	30	1.4
No response	79	3.8
All applicable	2,091	100.0

Table 23. — Things consumers indicated they dislike most about sweet potatoes

Dislike most about sweet potatoes	Households Number	Households Percent
Nothing in particular	1,117	53.4
Sometimes stringy	216	10.3
High calories	153	7.3
Sweet taste	122	5.9
Difficult to prepare	106	5.1
Sometimes have hard spots	80	3.8
Price too high	46	2.2
Spoil fast	44	2.1
Sometimes strong or bitter	28	1.4
Too dry	23	1.1
Inconsistent size	21	1.0
Prepackaging	13	0.6
Tough	10	0.5
Too soft, mushy, or overcooked	13	0.6
No response	99	4.7
All applicable	2,091	100.0

Fresh Sweet Potato Preferences. — Respondents who used fresh sweet potatoes were shown visuals illustrating a range of sizes, shapes, external colors, and internal colors of fresh sweet potatoes. They were asked to select their preferences for each of the four characteristics. Each selection was recorded by the interviewer according to an identification number on the visual.

Sizes were illustrated in terms of diameter, in ½-inch intervals, ranging from 1½ inches to 4 inches. Forty-six percent of the consumers selected a sweet potato 2½ inches in diameter as the preferred size. The preference for 30 percent was the next adjacent size of 3 inches. Preferences for the 2-inch and 3½-inch sizes were indicated by 9 and 12 percent, respectively (Figure 1).

Six basic shapes of the sweet potato were represented in visuals shown to respondents. Preferences of most consumers were distributed among three basic shapes. A uniformly tapered (eliptical) sweet potato was selected by 39 percent. Twenty-six percent selected a slightly rounded shape, and 20 percent indicated a preference for sweet potatoes with a slightly elongated shape. Some indicated preferences for either round or elongated sweet potatoes, but very few selected the banana (rooty) shape (Figure 2).

Color gradations ranging from purple to cream white were used to represent external color of fresh sweet potatoes. Preferences were concentrated in two intermediate groups (Figure 3). Approximately 66 percent expressed preferences for copper colors. Preferences for rose colored sweet potatoes were indicated by almost 28 percent. Very few expressed preferences for the purple, tan, or the cream white colors.

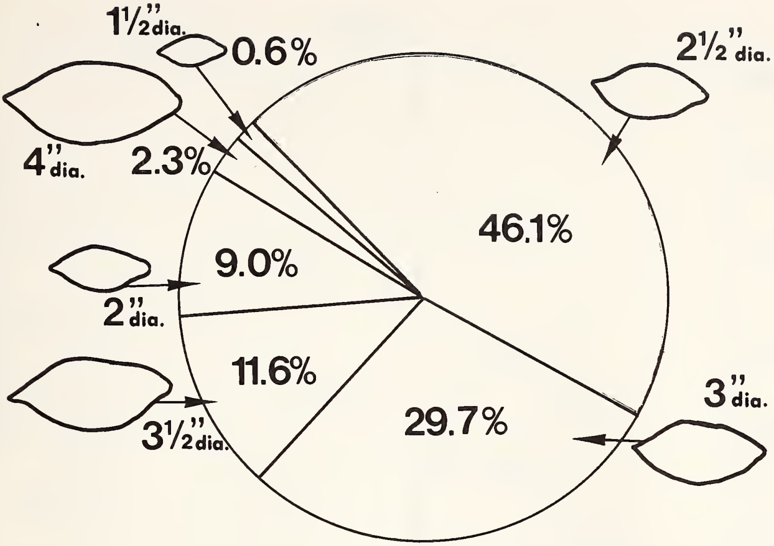

Figure 1. — Size of fresh sweet potatoes preferred by consumers, five northeastern U.S. cities, 1975.

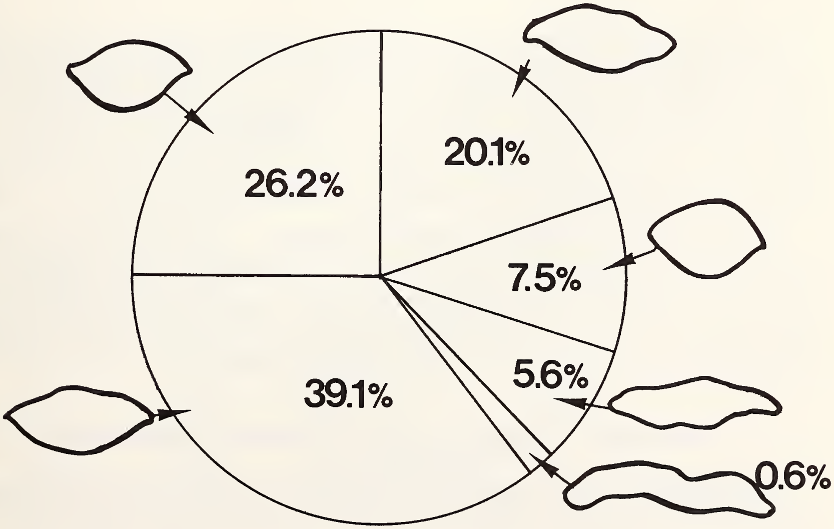

Figure 2. — Shape of fresh sweet potatoes preferred by consumers, five northeastern U.S. cities, 1975.

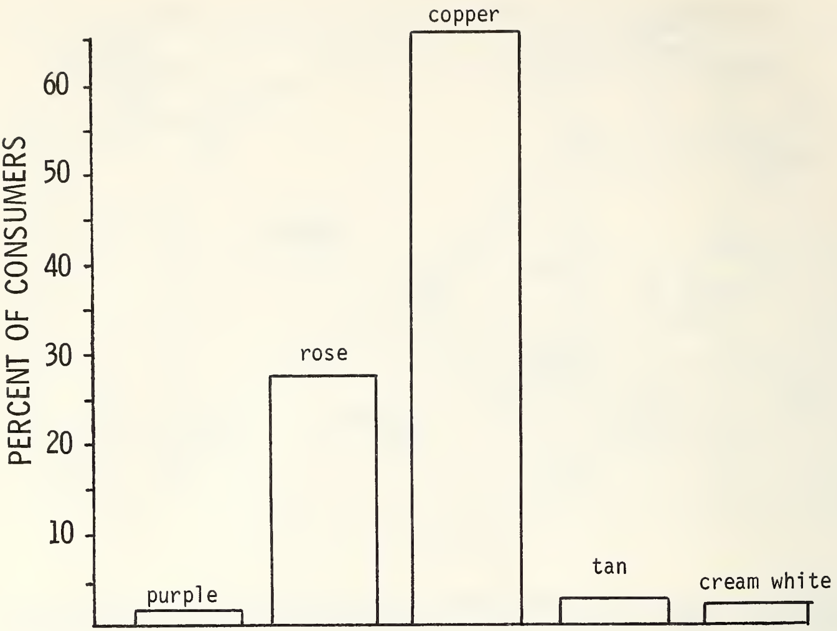

Figure 3. — External color of fresh sweet potatoes preferred by consumers, five northeastern U.S. cities, 1975.

Internal color of fresh sweet potatoes was represented by color gradations ranging from deep orange to cream white. Preferences were strong for the darker internal colors (Figure 4). Deep orange was preferred by 60 percent of the respondents. More than 21 percent expressed a preference for orange, and 13 percent for light orange. Relatively few consumers expressed preferences for the yellow or white internal colors.

Processed Sweet Potato Color Preferences. — Consumers were asked to select their preferences from a visual illustrating color gradations of processed sweet potatoes, ranging from deep orange to light yellow. Strong preferences were indicated for the darker colors. More than 76 percent chose the deep orange and orange colors (Figure 5).

Consumer Suggestions for Product Improvement

All consumers who used sweet potatoes were asked what they thought needed to be done to make them better satisfied with fresh and with processed sweet potatoes.

Fresh Sweet Potatoes. — When asked about fresh sweet potatoes, approximately 36 percent said "nothing needs to be done" to make them

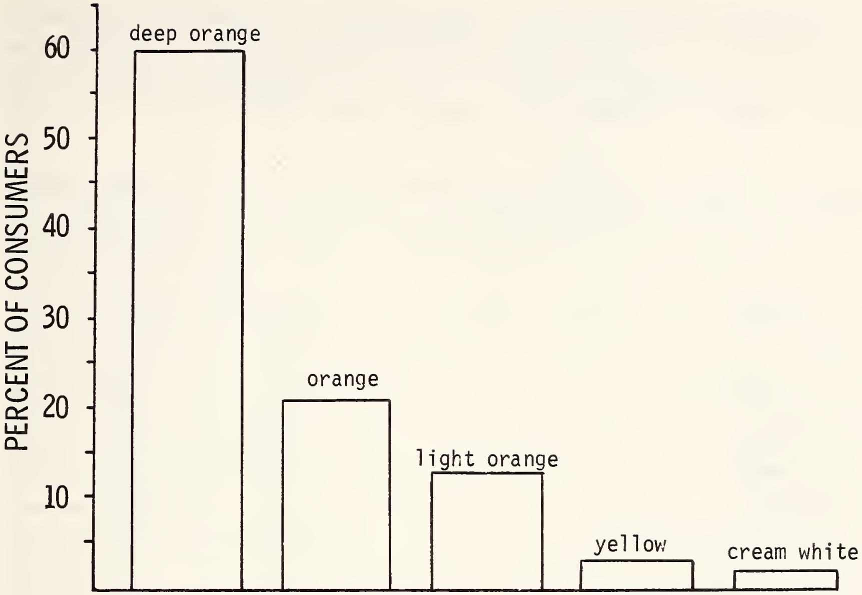

Figure 4. — Internal color of fresh sweet potatoes preferred by consumers, five northeastern U.S. cities, 1975.

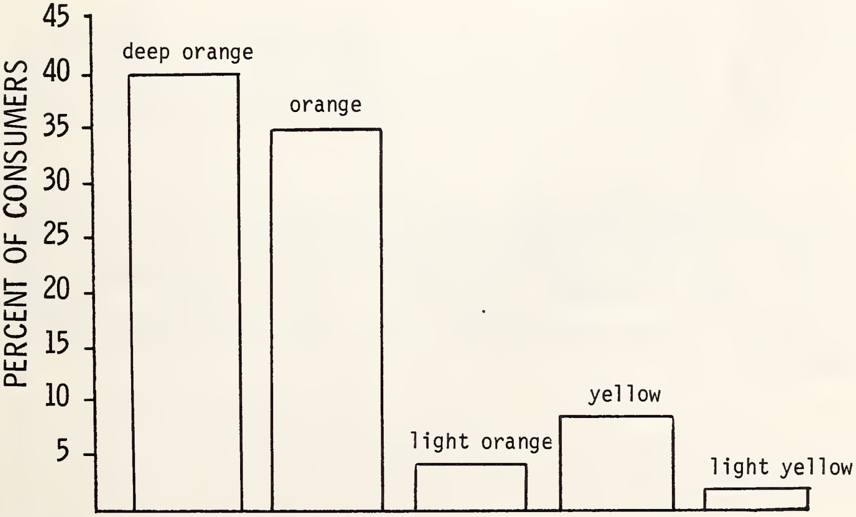

Figure 5. — Color of processed sweet potatoes preferred by consumers, five northeastern U.S. cities, 1975.

better satisfied with the product. Other responses were varied. Suggestions mentioned relatively frequently were "eliminate stringiness," "pack more uniform size," "reduce price," "don't prepackage," "increase shelf life," "improve shape," and "need smoother skin" (Table 24).

Table 24. — What consumers think needs to be done to fresh sweet potatoes to make them better satisfied with the product

Things which would make consumers better satisfied	Households	
	Number	Percent
Nothing	747	35.7
Eliminate stringiness	130	6.2
Pack more uniform size	120	5.7
Reduce price	96	4.6
Don't prepackage	65	3.1
Increase shelf life	60	2.9
Improve shape	55	2.6
Need smoother skin	47	2.2
Don't ship off-grade material	40	1.9
Eliminate hard spots	37	1.8
Need to be juicier, improve flavor	30	1.4
Need darker skin color	26	1.3
Pack more consistent quality	22	1.1
Need to be firmer	17	0.8
Increase availability	17	0.8
Don't ship green sweet potatoes	16	0.8
Need to reduce calories	15	0.7
Provide educational material and recipes	10	0.5
Reduce damage in handling	8	0.4
Need to be drier	8	0.4
Don't know	106	5.1
No response	419	20.0
All applicable	2,091	100.0

Processed Sweet Potatoes. — About 35 percent of the respondents said that nothing was needed to make them better satisfied with processed sweet potatoes. Suggestions mentioned most frequently by the remaining consumers included "eliminate sogginess," "improve flavor," "increase availability," "greater quality control," and "improve color and texture" (Table 25).

Table 25. — What consumers think needs to be done to processed sweet potatoes to make them better satisfied with the product

Things which would make consumers better satisfied	Households	
	Number	Percent
Nothing	736	35.2
Eliminate sogginess	146	7.0
Improve flavor	134	6.4
Increase availability	133	6.4
Greater quality control	103	4.9
Eliminate stringiness	98	4.7
Increase firmness	91	4.3
Reduce amount of liquid in cans	62	3.0
Improve color and texture	29	1.4
Reduce price	29	1.4
Need to be juicier	26	1.2
Provide greater choice of can sizes	22	1.1
Reduce calories	13	0.6
Use larger slices or wholes in can	12	0.6
Pack ready-to-serve in candied form	11	0.5
Some need to be softer	6	0.3
Provide educational materials and recipes	5	0.2
Don't know	95	4.5
No response	340	16.3
All applicable	2,091	100.0

Implications

Nonusers. — Most nonusers do not avoid sweet potatoes for reasons having to do with product quality. The majority are nonusers because their tastes and preferences are not favorable to the sweet potato. They simply don't like sweet potatoes, or don't care for the sweet taste in a potato-type food (some 12 percent of the households). Unless their tastes and preferences change, they must be considered out of the potential market for sweet potatoes. A portion of the nonusers who avoid the sweet potato for reasons other than tastes and preferences may be potential users if they are convinced that sweet potatoes are not too much trouble to prepare, or that they are not too high in calories.

Frequency of Use. — Most consumers who use sweet potatoes purchase them infrequently. The product holds a cool-weather-holiday image for many, somewhat similar to that of turkey or cranberries a few years ago. Promotional efforts might encourage more frequent use of sweet potatoes for reasons not confined to holiday meals. The potential for increasing sweet potato consumption beyond the traditional holiday pattern could be highly significant.

High Calorie Image. — The data clearly show that many consumers class sweet potatoes in the high calorie food group. In fact, the sweet potato is not among the foods that are highest in calories. Furthermore, the calorie level of sweet potato dishes depends partly upon the method of preparation, including additives such as sugar and butter. Promotional activities need to include information to clarify this point and to emphasize the nutritional value of the sweet potato.

Need for Consumer Information. — Many consumers are unaware of the recommended procedures for handling and storing fresh sweet potatoes. Consequently, they may become disenchanted with the product if it goes bad. This could be avoided if consumers were adequately informed.

Prepackaging. — Many retailers offer sweet potatoes in prepackaged form only. The prepackaged product reflects the material shipped to market — the full range of sizes, shapes, etc. Prepackaging may be used as a means of selling the variation received by the retailer. Otherwise some of the undersirable sizes and shapes that get to market are passed over in the open bin and eventually deteriorate. Many consumers want to buy a certain number of sweet potatoes that are relatively uniform. They don't want to be forced to take all sizes and shapes that go into a prepackaged unit. Faced with this situation, some probably choose the alternative of not buying sweet potatoes. Others probably buy reluctantly and less frequently.

Need for Greater Uniformity in Fresh Pack. — Sweet potatoes packed for fresh market need to be more uniform in quality, particularly as regards sweet potato size and shape. The data strongly suggest that fresh sweet potatoes should be rigorously size-graded into rather narrow ranges within a shipping container so that the largest root does not exceed the smallest by more than about ½ inch in diameter. Different size groups could be shipped in separate containers. Such packs would have greater consumer appeal, an important consideration in view of the longtime decline in per capita consumption of this product. The development of an efficient technique for rigorous size-grading of sweet potatoes would be needed to facilitate this change.

Public Eating Places. — There is some indication of the need for improved methods of preparation to gain greater consumer acceptance of sweet potatoes served in public eating places.

Consumer Preferences. — The preferences of consumers as regards the color of processed sweet potatoes, the external and internal color of fresh sweet potatoes, and the size and shape of fresh sweet potatoes were made explicit by visuals used in this study. Other quality factors were rated by consumers. Preference ratios, and the likes and dislikes expressed by consumers, should be used as guides in sweet potato breeding programs, in production programs, and in packing or processing operations.

Preferences for certain quality factors also may have implications for current grade standards. The range in quality of sweet potatoes currently going to market extends significantly beyond the preference limits of most consumers.

APPENDIX A

Methodology

Sample Design

The 2,525 observations included in the study were a sample of households from the metropolitan areas of Milwaukee (Wisconsin), Cincinnati (Ohio), Pittsburgh (Pennsylvania), Rochester (New York), and Boston (Massachusetts).[4] For purposes of the study, a household was considered to be any occupied dwelling with cooking facilities. A personal interview was conducted with the individual primarily responsible for decisions on purchasing food items for the household. If sweet potatoes had been prepared and served within the household during the year preceding the interview, the household was considered a user. Otherwise, it was classified as a nonuser. Both users and nonusers were included in the survey.

Sampling Method

Household interviews were done under contract with a marketing research firm in each of the five cities.[5] Sampling was done on the basis of user household quotas for each city. However, limited information was obtained from all nonuser households encountered in the process of fulfilling user quotas. Sampling segments were selected at random from geographic strata of the metropolitan area of each city.[6] Sampling segments consisted of sections of streets identified on a map of the metropolitan area. User household subquotas were assigned to geographic strata approximately in proportion to population density. Interviewers were assigned designated segments and instructed as to starting point and street side to begin interviews. Each household on the designated side of the street was to be included in the sample up to the point of a predetermined user quota. If there was no response at a household on the initial visit, or if the individual primarily responsible for food purchase decisions was not at home, one call back was made in the evening. If the primary household could not be contacted, or was not a user, the household directly across the street was used as an alternate. If the alternate household could not be contacted, or was not a user, the household to the right of the alternate was used. The household to the left was used as a third alternate, if needed. If the assigned

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[4] The sample is estimated to be approximately 0.1 percent of the population of the metropolitan areas of the five cities.

[5] Interviewing was done under contract by the following firms: Bisbing Business Research, Milwaukee, Wisconsin; B and B Research Services, Inc., Cincinnati, Ohio; Anita Grupp Field Research Service, Pittsburgh, Pennsylvania; Slade Research Associates, Inc., Rochester, New York, and Performance Plus, Framingham, Massachusetts.

[6] An average of approximately 60 sample segments per city was selected. Occasionally a segment fell within a neighborhood deemed unsafe for interviews. When this happened, a replacement segment was selected at random.

user household quota was not filled from a given sample segment, a predetermined alternate segment in the vicinity was utilized under the same procedure until the quota was filled. No deviation from the specified procedure was permitted.

Sampling Reliability

The confidence limits for sample percentages presented in this report are estimated on an approximate basis in the table below.

Approximate Confidence Limits
(Two standard errors)

Size of sample or subgroup sample	For percentages around				
	50	40 or 60	30 or 70	20 or 80	10 or 90
2500	1.96	1.92	1.80	1.57	1.18
2100	2.14	2.10	1.96	1.71	1.28
1600	2.45	2.40	2.25	1.96	1.47
1500	2.53	2.48	2.32	2.02	1.52
1400	2.62	2.57	2.40	2.10	1.57
1300	2.72	2.66	2.49	2.17	1.63
1100	2.95	2.90	2.71	2.36	1.77
900	3.27	3.20	2.99	2.61	1.96
800	3.46	3.39	3.18	2.77	2.08
600	4.00	3.92	3.67	3.20	2.40
500	4.38	4.29	4.02	3.51	2.63
400	4.90	4.80	4.49	3.92	2.94
200	6.93	6.79	6.35	5.54	4.16
100	9.80	9.60	8.98	7.84	5.88

The probability is 95 in 100 that the sample percentages will not vary, plus or minus, by more than the indicated amount from the results that would have been obtained by interviewing all households in the study areas. For example, 17.2 percent of all households in the survey were classified as nonusers of sweet potatoes. The chances are 95 in 100 that the percentage of nonusers among all households in the study areas would be between 15.6 and 18.8 percent. The possible sampling variation would be larger for subgroup samples because they include a smaller number of interviews.

Aside from possible errors in consumer response and in the recording of responses, two sources of nonchance variation could affect the magnitude of the confidence limits presented. Occasionally, a sample segment fell within a neighborhood deemed unsafe for interviewers. Such segments were replaced with an alternate segment selected at random. Also, where a primary household could not be included as a user or nonuser (not at home on first and callback visits, or refused to be interviewed), an alternate household was specified as explained earlier. To the extent that occasional unsafe sample segments or missed primary households may differ from the sample obtained, the confidence limits presented are understated.

APPENDIX B

Findings presented in the following tables are from a consumer survey conducted in 1975 in the metropolitan areas of Milwaukee (Wisconsin), Cincinnati (Ohio), Pittsburgh (Pennsylvania), Rochester (New York), and Boston (Massachusetts).

Appendix Table 1.--Classification of respondents by type of employment

Type of employment of head of household	Households: Use sweet potatoes Number	Households: Use sweet potatoes Percent	Households: Nonusers Number	Households: Nonusers Percent
Professional or technical	485	23.2	102	23.5
Managerial	233	11.1	45	10.4
Clerical	68	3.3	22	5.1
Sales worker	138	6.6	23	5.3
Service worker	172	8.2	29	6.7
Skilled labor	245	11.7	47	10.8
Semiskilled labor	288	13.8	49	11.3
Unskilled labor	33	1.6	11	2.5
Retired or unemployed	372	17.8	66	15.2
No response	57	2.7	40	9.2
Total	2,091	100.0	434	100.0

Appendix Table 2.--Classification of user and nonuser respondents by income group

Family income before taxes	Households: Use sweet potatoes Number	Households: Use sweet potatoes Percent	Households: Nonusers Number	Households: Nonusers Percent
Less than $3,000	72	3.4	10	2.3
$3,000 to $4,999	114	5.5	18	4.1
$5,000 to $7,999	140	6.7	26	6.0
$8,000 to $9,999	202	9.7	38	8.8
$10,000 to $14,999	574	27.4	123	28.3
$15,000 to $24,999	540	25.8	101	23.3
$25,000 or more	203	9.7	41	9.4
No response	246	11.8	77	17.8
Total	2,091	100.0	434	100.0

Appendix Table 3.--Classification of user and nonuser respondents by age group

Age group of respondent	Households			
	Use sweet potatoes		Nonusers	
	Number	Percent	Number	Percent
Under 25	82	3.9	30	6.9
25 - 35	481	23.0	146	33.6
36 - 50	729	34.9	121	27.9
51 - 65	555	26.6	78	18.0
66 and over	239	11.4	44	10.1
No response	5	.2	15	3.5
Total	2,091	100.0	434	100.0

Appendix Table 4.--Classification of user and nonuser respondents by level of schooling

Level of school completed	Households			
	Use sweet potatoes		Nonusers	
	Number	Percent	Number	Percent
Elementary or part high school	336	16.1	44	10.1
High school	969	46.3	203	46.8
Some college or vocational training	400	19.1	90	20.7
College degree or beyond	368	17.6	75	17.3
No response	18	.9	22	5.1
Total	2,091	100.0	434	100.0

Appendix Table 5.--Classification of user and nonuser respondents by race

Race	Households			
	Use sweet potatoes		Nonusers	
	Number	Percent	Number	Percent
White	1,990	95.2	410	94.5
Nonwhite	89	4.2	8	1.8
Not specified	12	.6	16	3.7
Total	2,091	100.0	434	100.0

Appendix Table 6.--Frequency of purchasing sweet potatoes, by income group of respondent

Times purchased during year	Income group of respondent															
	Less than $3,000		$3,000 to $4,999		$5,000 to $7,999		$8,000 to $9,999		$10,000 to $14,999		$15,000 to $24,999		$25,000 or more		No response	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1	9	12.5	4	3.5	18	12.9	26	12.9	62	10.8	68	12.6	27	13.2	25	10.2
2	14	19.4	16	14.0	30	21.4	32	15.8	103	17.9	89	16.5	33	16.2	53	21.6
3	7	9.7	16	14.0	16	11.4	25	12.4	75	13.1	71	13.1	25	12.2	34	13.9
4	9	12.5	13	11.4	17	12.2	22	10.9	63	11.0	69	12.8	23	11.3	38	15.5
5	4	5.6	13	11.4	8	5.7	11	5.4	44	7.7	31	5.7	15	7.3	14	5.7
6	3	4.2	11	9.7	16	11.4	22	10.9	63	11.0	61	11.3	25	12.2	21	8.6
7	2	2.8	0	0.0	2	1.4	0	0.0	5	0.9	3	0.6	4	2.0	4	1.6
8	3	4.2	5	4.4	0	0.0	5	2.5	7	1.2	8	1.5	4	2.0	5	2.1
9	0	0.0	0	0.0	0	0.0	1	0.5	2	0.3	1	0.2	0	0.0	3	1.2
10	5	6.9	4	3.5	4	2.9	4	2.0	21	3.7	16	3.0	1	0.5	4	1.6
11	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	1	0.2	0	0.0	0	0.0
12	6	8.3	19	16.7	14	10.0	30	14.8	70	12.2	66	12.2	20	9.8	24	9.8
13 - 24	7	9.7	5	4.4	6	4.3	11	5.4	33	5.7	38	7.0	20	9.8	13	5.3
25 - 48	2	2.8	5	4.4	6	4.3	6	3.0	14	2.4	11	2.0	5	2.5	6	2.5
49 - over	1	1.4	3	2.6	2	1.4	7	3.5	9	1.6	5	0.9	2	1.0	1	0.4
No response	0	0.0	0	0.0	1	0.7	0	0.0	2	0.3	2	0.4	0	0.0	0	0.0
Total	72	100.0	114	100.0	140	100.0	202	100.0	574	100.0	540	100.0	204	100.0	245	100.0

Appendix Table 7.--Frequency of purchasing sweet potatoes, by age group of respondent

Times purchased during year	Age group of respondent											
	Under 25		25-35		36-50		51-65		66 and over		No response	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1	12	14.6	79	16.4	82	11.2	43	7.8	24	10.0	0	0.0
2	13	15.9	102	21.2	123	16.8	92	16.6	39	16.3	1	20.0
3	13	15.9	55	11.5	99	13.6	68	12.3	33	13.8	1	20.0
4	11	13.4	51	10.6	85	11.6	73	13.2	33	13.8	1	20.0
5	10	12.2	34	7.1	46	6.3	32	5.8	17	7.1	1	20.0
6	4	4.9	51	10.6	78	10.7	65	11.7	24	10.0	0	0.0
7	0	0.0	5	1.0	7	1.0	6	1.1	2	0.8	0	0.0
8	1	1.2	4	0.8	12	1.6	15	2.7	5	2.1	0	0.0
9	0	0.0	0	0.0	4	0.6	3	0.5	0	0.0	0	0.0
10	3	3.6	16	3.3	17	2.3	14	2.5	8	3.4	1	20.0
11	0	0.0	2	0.4	0	0.0	0	0.0	0	0.0	0	0.0
12	5	6.1	38	7.9	96	13.2	83	15.0	27	11.3	0	0.0
13 - 24	2	2.4	27	5.6	54	7.4	36	6.5	14	5.9	0	0.0
25 - 48	4	4.9	8	1.7	17	2.3	17	3.0	9	3.8	0	0.0
49 - over	4	4.9	9	1.9	6	0.8	6	1.1	4	1.7	0	0.0
No response	0	0.0	0	0.0	4	0.6	1	0.2	0	0.0	0	0.0
Total	82	100.0	481	100.0	730	100.0	554	100.0	239	100.0	5	100.0

Appendix Table 8.--Frequency of purchasing sweet potatoes, by race of respondent

Times purchased during year	Race of respondent					
	White		Nonwhite		Not specified	
	Number	Percent	Number	Percent	Number	Percent
1	231	11.6	7	7.8	2	16.7
2	363	18.3	7	7.8	0	0.0
3	263	13.2	5	5.5	1	8.3
4	244	12.3	7	7.8	3	25.0
5	131	6.6	4	4.4	2	16.7
6	212	10.7	9	10.0	1	8.3
7	19	0.9	0	0.0	1	8.3
8	35	1.8	2	2.2	0	0.0
9	6	0.3	1	1.1	0	0.0
10	49	2.5	8	8.9	2	16.7
11	1	0.1	1	1.1	0	0.0
12	234	11.8	15	16.7	0	0.0
13 - 24	122	6.1	11	12.2	0	0.0
25 - 48	48	2.4	7	7.8	0	0.0
49 - over	23	1.2	6	6.7	0	0.0
No response	5	0.2	0	0.0	0	0.0
Total	1,989	100.0	90	100.0	12	100.0

Appendix Table 9.--Where consumers usually bought their fresh sweet potatoes

Source of sweet potatoes	Households	
	Number	Percent
Food store	1,455	90.9
Farmers' market	62	3.9
Roadside stand	58	3.6
Other	13	0.8
No response	13	0.8
Total	1,601	100.0

Appendix Table 10.--When sweet potatoes were purchased by consumers who bought the product only during certain months

Month sweet potatoes purchased	Households	
	Number	Percent
January	0	0.0
February	0	0.0
March	2	0.3
April	2	0.3
May	2	0.3
June	3	0.4
July	3	0.4
August	2	0.3
September	6	0.8
October	10	1.3
November	99	12.9
December	16	2.1
November-December	298	38.7
Fall months	38	4.9
Winter months	184	23.9
November-March	93	12.1
No response	11	1.4
Total	769	100.0

Appendix Table 11.--Consumer indications of problems with sweet potatoes going bad in storage

Response	Households	
	Number	Percent
Experienced problems with stored sweet potatoes	244	16.7
No problem with stored sweet potatoes	1,191	81.3
No response	30	2.0
Total	1,465	100.0

Appendix Table 12.--Consumer indication of satisfaction with the size, shape, external color, and internal color of fresh sweet potatoes

Item	Response					
	Satisfied		Not satisfied		No response	
	Number	Percent	Number	Percent	Number	Percent
Size	1,348	84.2	245	15.3	8	0.5
Shape	1,469	91.8	124	7.7	8	0.5
External color	1,509	94.2	83	5.2	9	0.6
Internal color	1,526	95.3	66	4.1	9	0.6

Appendix Table 13.--Consumer rating of the baking quality of fresh sweet potatoes

Rating*	Households Number	 Percent
1	279	17.4
2	337	21.0
3	375	23.4
4	272	17.0
5	206	12.9
6	47	2.9
7	32	2.0
8	17	1.1
9	6	0.4
No response	30	1.9
Total	1,601	100.0

* - Based on a scale of 1 to 9, with 1 = desirable and 9 = undesirable

Appendix Table 14.--Consumer rating of the texture of fresh sweet potatoes

Rating*	Households Number	 Percent
1	296	18.5
2	420	26.2
3	409	25.6
4	206	12.9
5	167	10.4
6	47	2.9
7	28	1.8
8	18	1.1
9	5	0.3
No response	5	0.3
Total	1,601	100.0

* - Based on a scale of 1 to 9, with 1 = desirable and 9 = undesirable

Appendix Table 15.--Consumer rating of the flavor of fresh sweet potatoes

Rating*	Households Number	 Percent
1	606	37.9
2	408	25.5
3	291	18.2
4	122	7.6
5	121	7.6
6	18	1.1
7	12	0.7
8	10	0.6
9	8	0.5
No response	5	0.3
Total	1,601	100.0

* - Based on a scale of 1 to 9, with 1 = desirable and 9 = undesirable

Appendix Table 16.--Consumer rating of the color of processed sweet potatoes

Rating*	Households	
	Number	Percent
1	364	22.7
2	353	22.0
3	309	19.3
4	171	10.7
5	148	9.2
6	39	2.4
7	21	1.3
8	11	0.7
9	13	0.8
No response	174	10.9
Total	1,603	100.0

* - Based on a scale of 1 to 9, with 1 = desirable and 9 = undesirable

Appendix Table 17.--Consumer rating of the texture of processed sweet potatoes

Rating*	Households	
	Number	Percent
1	234	14.6
2	314	19.6
3	281	17.5
4	201	12.5
5	215	13.4
6	84	5.3
7	63	3.9
8	25	1.6
9	14	0.9
No response	172	10.7
Total	1,603	100.0

* - Based on a scale of 1 to 9, with 1 = desirable and 9 = undesirable

Appendix Table 18.--Consumer rating of the flavor of processed sweet potatoes

Rating*	Households	
	Number	Percent
1	288	18.0
2	343	21.4
3	277	17.3
4	167	10.4
5	203	12.7
6	59	3.7
7	49	3.0
8	20	1.2
9	25	1.6
No response	172	10.7
Total	1,603	100.0

* - Based on a scale of 1 to 9, with 1 = desirable and 9 = undesirable

Appendix Table 19.--Consumer rating of the overall quality of frozen sweet potatoes

Rating*	Households Number	Percent
1	21	32.8
2	12	18.7
3	11	17.2
4	6	9.4
5	4	6.2
6	1	1.6
7	2	3.1
8	1	1.6
9	6	9.4
No response	0	0.0
Total	64	100.0

* - Based on a scale of 1 to 9, with 1 = desirable and 9 = undesirable

Appendix Table 20.--Reasons given by consumers who gave unfavorable ratings to the overall quality of frozen sweet potatoes

Reason for unfavorable rating	Households Number	Percent
Too sweet	3	30.0
Tasteless	3	30.0
Poor quality	1	10.0
No response	3	30.0
Total	10	100.0

Appendix Table 21.--Consumer indications of satisfaction and dissatisfaction with sweet potatoes consumed in public eating places

Response	Households Number	Percent
Satisfied	470	76.7
Not satisfied	135	22.0
No response	8	1.3
Total	613	100.0

Appendix Table 22.--Reasons given by consumers who were dissatisfied with sweet potatoes consumed in public eating places

Reason for dissatisfaction	Households Number	 Percent
Tasteless; not seasoned	40	29.6
Watery, mushy	22	16.3
Not appealing	20	14.8
Hard and dry	13	9.6
Too sweet	10	7.4
Fiberous	7	5.2
Overcooked	4	3.0
No response	19	14.1
Total	135	100.0

April 1978

Bulletin No. 707

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MORTALITY and LONGEVITY in LOUISIANA: The Relationship of Rural Residence to Survival after Age 65

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Acknowledgment

The authors are deeply in debt to Ernie Helen Atkins, former statistical officer of the Louisiana State Health Department, from whom much of the data used in this study were obtained.

Mortality and Longevity in Louisiana: The Relationship of Rural Residence to Survival After Age 65

YUI-HUEN KWAN AND ALVIN L. BERTRAND*

Introduction

The Problem

With the coming of the Industrial Revolution and advances in science, there has been a general improvement in socio-economic status and particularly in levels of living in the Western world. In the United States, one of the most obvious changes accompanying this trend has been the dramatic increase in the numbers of older people (see Table 1). In 1900 there were slightly more than 3 million older people (65 years of age and over) in the United States. By 1940, the number had tripled to 9 million, and at the time of the most recent census, in 1970, 20 million persons aged 65 and over were enumerated. It is expected that this number will reach 29 million by the year 2000. Twenty years later, in the year 2020, there might well be over 40 million elderly in this country. The dramatic increase in the aged in the U.S. may be emphasized as follows. In one century, from 1900 to 2000, the elderly population will have increased from 3 million to 29 million—an almost tenfold growth. During the same century, the nation's population will have increased at the very most fourfold. (Bouvier, 1973:39; Stockwell, 1973:3-5; Riley, Johnson, and Foner, 1972:34; Tibbits, 1960:13; Siegel and O'Leary, 1973:2).

Trends toward the aging of the population in Louisiana have paralleled that of the nation (see Table 2). The population age 65 years and over in the state was about 350,000 in 1977 and is projected to reach approximately 450,000 by the year 2000. This shows the current and future importance of the aged among the population of the state.

The relative increase in the number of aged in the U.S. and Louisiana has resulted from several factors. First, births have decreased more or less steadily over the past 100 years. Second, a larger proportion of those born are now surviving to age 65 and over than was formerly the case. Third, the large numbers of people who migrated to the United States in the late 19th and early 20th centuries have reached this age group. Of these factors, the

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Table 1. — Percent of population 65 and over, U.S., for selected years, 1900-2000

Population Aged 65 and Over	Year 1900	1930	1940	1950	1960	1970	2000
Percent	4.0	5.4	6.8	8.1	9.2	9.6	11.1
Number	3,080,498	6,633,805	9,019,314	12,269,537	16,525,037	20,065,520	30,600,000

Sources: R. C. Atchley, *The Social Forces in Later Life*. (Belmont, California: Wadsworth Publishing Company, 1972;). U.S. Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970,* Bicentennial Edition, Part 1. (Washington D.C.: U.S. Governmet Printing Office, 1975), p. 15.

Table 2. — Percent of population 65 and over, Louisiana, for selected years, 1900-2000

Population Aged 65 And Over	Year 1900	1930	1940	1950	1960	1970	2000
Percent	2.9	3.6	5.0	6.5	7.4	8.4	9.7
Number	40,223	75,657	118,194	174,432	241,019	306,707	449,936

Sources: U.S. Census Office, Abstract of the Twelfth Census of the United States, 1900, Table 50, (Washington, D.C.: U.S. Government Printing Office, 1902); P. W. Ryan, *The State of the State in 1976: An Economic and Social Report to the Governor*. (Louisiana State Planning Office, 1976), p. 10.

decreasing relative size of the baby crop is by far the most important (Sheldon, 1960:41).

An aging population has focused national attention on longevity. Mass media coverage of topics related to this subject has been exceptionally high in recent years. Two stories in *Newsweek*, entitled respectively "How Long Will I Live?" (1977:6-7) and "The Graying of America" (1977:50-65), illustrate one approach found in popular literature. Another approach is illustrated by four articles appearing in *U.S. News and World Report* in 1976: "Next 25 Years — How Your Life Will Change" (1976:39-42); "How To Enjoy a Longer Life" (1976:29-32); "How To Eat Right and Live Longer" (1976:37-40); and "As U.S. Death Rate Hits Historic Low" (1976:47). The third emphasis in popular literature is on longevity per se. This emphasis is illustrated by such articles as appeared in *National Geographic* (Leaf, 1973:93-119) about remote villages in Ecuador and the Soviet Union, where persons are said to live to the advanced age of 125 or more. Newspaper headlines such as "Why They Live to Be 100, or Even Older" (New York Times Magazine, 1971:3, 28-34) also indicate the popularity of longevity themes.

Biological factors set the physical parameters within which the human organism can live, including the limits of life. Parenthetically it may be noted some biologists are predicting that we stand on the brink of a scientific breakthrough regarding the biological makeup of man which will add from 25 to 30 years to the average life-span (Sobel, 1966:132-136; Rosenfeld, 1976:40-46). However, nonbiological factors add or subtract a dimension to biological parameters. To date, relatively little analysis of the relationship between social variables and longevity has been carried out. If scientists wish to increase longevity, they will have to understand all the factors which contribute to longer life so that they can manipulate these factors to regulate the morphology of the aging process (Palmore, 1971:7). Some nonbiological factors have already been identified as related to longevity, such as marital status, occupation, and social stress, but there are undoubtedly others. Dodge and Martin (1971:28) conclude in their study of the relation of social stress to chronic illness that, "To the extent that mortality rates bear meaningful relationship to the organization of society, its level of development, and the efficiency of its operation, the phenomenon of mortality deserves as much recognition and attention from sociologists as they give fertility and migration." This gap in knowledge provided the incentive for the research reported in this bulletin (Barclay, 1958:145-146; Rose, 1971:13-29; Palmore, 1971:3-12; and Rao, 1973:405).

Objectives of the Study

The overall objective of the study was to provide detailed information on longevity and trends in longevity in Louisiana. Since previous studies of mortality and/or longevity generally have been done within the framework of the total population of the United States, or for selected population groups within a state, this study will fill a gap in data at the state level.

The existence of significant differences between populations living in the open country or small villages and those living in cities has been recognized for thousands of years. The rural dweller has been distinguished from the urban resident by an elaborate and seemingly endless list of social, cultural, and economic differentials. In keeping with this social fact, the specific objective of this study was the determination of the effect of place of residence, rural or urban, on longevity, after the age of 65 was reached.

Sex and race are also socially important variables which have been related to longevity. A secondary objective of this study was thus to evaluate the importance of these factors as longevity predictors within the constraints of rural and urban populations.

Methodology and Procedures

Source of Data

The setting for the present study was the state of Louisiana. The source of data was the U.S. Decennial Census of Population and the death certificates issued in Louisiana between 1962 and 1974, which were made available by the Director of the Louisiana State Bureau of Vital Statistics.

The subjects for the study consisted of all those persons 65 or over who died or survived in Louisiana during the period 1962 to 1974. Inclusion in the study population of those dying was determined by the following characteristics:

(1) people 65 years of age or over,
(2) Louisiana resident at time of death, and
(3) death not due to external violence (i.e., accident, suicide, and homicide).

Since the number of deaths and the number of persons surviving to older ages in a given year is relatively large, every third year during the period was used as a sample year — that is, 1962, 1965, 1968, 1971, and 1974.

Definition of Longevity

Questions about longevity, as stated earlier, have attracted the attention of scientists and non-scientists for a long time. Despite this interest, no generally accepted definition of "longevity" appears in the literature devoted to this subject. In some published works the term "longevity" is used to mean age at death, in others the reference is to "average life-span" or "maximal life-span" (Sobel, 1966:132-133, 136; Sachuk, 1970:262). Such variation in meaning makes it difficult to compare the findings obtained in different studies. Therefore, in this report longevity is defined simply as the age at death. This usage may be challenged in a technical sense, but it was considered appropriate for the purposes of the study.

Definition of Residence

Over the years, the United States Bureau of the Census has employed several definitions for differentiating the nation's population into rural and urban components (Cole, 1958:5). The definition adopted for the present study is the one utilized for the 1970 Census of the U.S. (1973:4-6). It is phrased as follows: the urban population consists of all persons living in (1) places of 2,500 inhabitants or more incorporated as cities, boroughs, villages, and towns, but excluding those persons living in the rural portions of extended cities; (2) unincorporated places of 2,500 inhabitants or more; and (3) other territory, incorporated or unincorporated, included in urbanized areas. The population not classified as urban constitutes the rural population.

Analytical Procedures

The methodological operations employed were designed to determine longevity trends in Louisiana and for the rural and urban components of the State's population from 1962 to 1974. Three different indices were constructed for validation and comparative purposes, the Comparative Mortality Index (CMI), the General Index of Longevity (GIL), and the Level of Longevity of the Elderly (LLE). Each may be explained briefly as follows:

(1) **The Comparative Mortality Index** (CMI): The CMI is a measure of relative mortality, usually employed to indicate changes over time in the overall mortality experience of an area. In order to compare the data collected across different years more meaningfully, it is necessary to employ a standardization technique. A shifting pattern of population weights is used to overcome the problem of prolonged use of a single standard age distribution (Shryock and Siegel, 1973:423). In this regard, the authors of this report were cognizant that changes in birth and migration rates would have effects on death rates. For this reason, an attempt was made to determine if changes occurred which might drastically affect the longevity measures used for comparing rural and urban residents. The trends in rural and urban birth rates were both found to have dropped over the 12 year period of the study, with the rural rate remaining somewhat lower in 1974 (9.3 as compared with 10.8 per 1000 persons). These differentials were not considered sufficient to affect mortality rates based on total populations. It was impossible to determine the original residence or destination of migrants, but it was determined that the residence composition of the state did not change greatly from 1962 to 1974.

The formula for the CMI is: $$\text{CMI} = \frac{\Sigma w_a m_a}{\Sigma w_a M_a}$$

where w_a is derived as follows: $$w_a = \frac{1}{2}\left(\frac{P_a}{P} + \frac{p_a}{p}\right)$$

P is the population of the standard or initial year, and p is the population of later years. P_a is the age-specific population of the standard year and p_a is the age-specific population of later years. M_a represents the age-specific death rates in the standard or initial year, m_a represents the age-specific death rate in later years (age-specific death rates are determined by dividing the number of persons dying in an age cohort by the number of persons in the total population and multiplying by a factor of 100 or 1000).

The above formula calls for taking a ratio of the weighted sum of age-specific death rates in each year to the similarly weighted sum of age-specific death rates of the initial year. The weights are the average of a) the proportion of the total population in the age group in the initial year and b) the corresponding proportion in each later year. The indices obtained relate the level of mortality in a given later year to the level of mortality in the starting or standard year. Since a different weighting pattern is used for each year, the CMI's for the various years are not fully comparable with one another. However, the weighting pattern is so similar from year to year that the ratios of CMI's may be considered satisfactory measures of relative mortality over short periods.

In addition to the calculation of CMI, an interpolation technique is used for inferring intermediate values in a given series of data, and an extrapolation technique is used for inferring values that go beyond the given series of data. The formula used is the Waring Formula, also known as the Lagrange Formula or the Waring-Lagrange Formula (Shryock and Siegel, 1973:681-684). This formula is used to derive the multipliers to interpolate or extrapolate for the f(x) value corresponding to a given x value.

(2) **The General Index of Longevity** (GIL): The source of data for the General Index of Longevity is the age distributions reported in population censuses (Sachuk, 1970:262-263). This index is computed by dividing the number of persons in a given age category (usually 80 and over) by the total population. In this study, the GIL is computed by dividing the total state population into the number of persons 80 years old and over in the total state population $\left(\frac{\text{Pop} \geq 80}{\text{Total Pop}}\right)$. Interpolation and extrapolation techniques are used for establishing values that cannot be obtained from census data.

(3) **The Level of Longevity of the Elderly (LLE):** The LLE also utilizes census data to determine longevity. The LLE differs from the GIL in that the proportion of persons 80 years and over is related not to the total population but to the number of elderly, i.e., persons 60 years and over $\left(\frac{\text{Pop} \geq 80}{\text{Pop} \geq 60}\right)$. This criterion depends on the birthrate and migration to a lesser degree than does the GIL. It is also presented in terms of percentages.

(4) **Bivariate Analysis:** In the second methodological operation designed to implement the data analysis, each independent variable (sex, race, and residence) of potential significance was compared with the dependent variable, longevity. The chi-square test was used as a measure of statistical significance for each comparison made (Leonard, 1976:176; Blalock, 1972:275). Analyses of the dependent and independent variable interrelationships were accomplished through the use of percentage tables. A comparison was also made of each sex and race variable while controlling for residence.

Mortality Characteristics of Persons Aged 65 and Over in Louisiana, 1962-1974

A brief description of the mortality characteristics of persons aged 65 and over in Louisiana during the study period provides a perspective for the analyses which follow. Mortality experience by sex, race, residence, and age-groups during the period 1962 to 1974 is presented to show variations in the study population.

Number of Deaths:

In Louisiana, 14,420 deaths (except for suicides, accidents, or homicides) of persons over 65 were recorded in 1962, 15,528 deaths occured in 1965, 16,207 in 1968, 16,018 in 1971, and 16,893 in 1974. Interestingly the crude death rate for persons 65 years and over in the state has been increasing slightly since 1962. In that year there were 4.27 deaths of persons in this age group per 1000 individuals in the state population. This rate increased slightly for each of the test years reaching 4.49 in 1974. The increase is undoubtedly related to the fact that the relative number of aged over 65 in the population also increased somewhat, from 7.46 percent to 8.95 percent.

The finding relative to the trends in death rate of persons 65 years of age and over which is most relevant to this study is the differential by residence. The death rate of ruralites remained much more stable from 1962 to 1974 than did the death rate of urbanites. The latter increased noticeably, from 2.51 persons per 1000 population to 2.67 persons per 1000 population. By contrast, the death rate of older persons living in rural areas only changed from 1.76 to 1.82 per 1000 persons. Since death rates were computed for persons 65 or over relative to each 1000 persons in the state's population, this is the first evidence that ruralites 65 years or older have an advantage in longevity over urbanites who have reached this age.

Geographic Distribution: Table 3 shows the distribution of deaths of persons 65 years and over among the 64 parishes for each study year. It can be seen that deaths increased through the years roughly paralleling the

Table 3. — Death of persons 65 and over in Louisiana, by parish, for selected years, 1962-1974

	1962		1965		1968		1971		1974	
Parish	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
Acadia	208	(1.4)	254	(1.6)	258	(1.6)	261	(1.6)	262	(1.6)
Allen	91	(0.6)	101	(0.7)	115	(0.7)	102	(0.6)	128	(0.8)
Ascension	133	(0.9)	113	(0.7)	128	(0.8)	134	(0.8)	156	(0.9)
Assumption	88	(0.6)	89	(0.6)	81	(0.5)	81	(0.5)	83	(0.5)
Avoyelles	206	(1.4)	250	(1.6)	250	(1.5)	239	(1.5)	240	(1.4)
Beauregard	108	(0.7)	119	(0.8)	147	(0.9)	130	(0.8)	144	(0.9)
Bienville	113	(0.8)	118	(0.8)	126	(0.8)	113	(0.7)	129	(0.8)
Bossier	146	(1.0)	174	(1.1)	182	(1.1)	180	(1.1)	206	(1.2)
Caddo	1024	(7.1)	1059	(6.8)	1149	(7.1)	1139	(7.1)	1244	(7.4)
Calcasieu	410	(2.8)	437	(2.8)	479	(3.0)	519	(3.2)	541	(3.2)
Caldwell	62	(0.4)	66	(0.4)	75	(0.5)	48	(0.3)	82	(0.5)
Cameron	20	(0.1)	23	(0.1)	29	(0.2)	25	(0.2)	30	(0.2)
Catahoula	78	(0.5)	70	(0.5)	62	(0.4)	67	(0.4)	76	(0.4)
Claiborne	119	(0.8)	155	(1.0)	131	(0.8)	152	(0.9)	135	(0.8)
Concordia	93	(0.6)	96	(0.6)	93	(0.6)	109	(0.7)	87	(0.5)
DeSoto	172	(1.2)	164	(1.1)	203	(1.3)	164	(1.0)	163	(1.0)
E. Baton Rouge	673	(4.7)	803	(5.2)	899	(5.5)	875	(5.5)	960	(5.7)
E. Carroll	95	(0.7)	93	(0.6)	90	(0.6)	78	(0.5)	75	(0.4)
E. Feliciana	71	(0.5)	83	(0.5)	87	(0.5)	84	(0.5)	66	(0.4)
Evangeline	168	(1.2)	175	(1.1)	178	(1.1)	188	(1.2)	157	(0.9)
Franklin	139	(1.0)	156	(1.0)	124	(0.8)	141	(0.9)	138	(0.8)
Grant	76	(0.5)	96	(0.6)	98	(0.6)	82	(0.5)	93	(0.6)
Iberia	194	(1.3)	218	(1.4)	245	(1.5)	230	(1.4)	256	(1.5)
Iberville	175	(1.2)	160	(1.0)	155	(1.0)	184	(1.1)	146	(0.9)
Jackson	85	(0.6)	89	(0.6)	94	(0.6)	106	(0.7)	109	(0.6)
Jefferson	562	(3.9)	636	(4.1)	740	(4.6)	895	(5.6)	1049	(6.2)
Jefferson Davis	131	(0.9)	123	(0.8)	145	(0.9)	138	(0.9)	157	(0.9)
Lafayette	284	(2.0)	287	(1.8)	310	(1.9)	323	(2.0)	389	(2.3)
Lafourche	188	(1.3)	207	(1.3)	210	(1.3)	202	(1.3)	217	(1.3)
LaSalle	66	(0.5)	80	(0.5)	72	(0.4)	95	(0.6)	97	(0.6)
Lincoln	120	(0.8)	144	(0.9)	134	(0.8)	156	(1.0)	173	(1.0)
Livingston	121	(0.8)	133	(0.9)	115	(0.7)	126	(0.8)	140	(0.8)

(continued)

Parish	1962		1965		1968		1971		1974	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
Madison	84	(0.6)	106	(0.7)	122	(0.8)	82	(0.5)	98	(0.6)
Morehouse	146	(1.0)	234	(1.5)	154	(1.0)	169	(1.1)	164	(1.0)
Natchitoches	197	(1.4)	203	(1.3)	247	(1.5)	207	(1.3)	237	(1.4)
Orleans	3441	(23.9)	3732	(24.0)	3641	(22.5)	3497	(21.8)	3386	(20.0)
Ouachita	453	(3.1)	500	(3.2)	519	(3.2)	473	(3.0)	504	(3.0)
Plaquemine	60	(0.4)	58	(0.4)	48	(0.3)	40	(0.2)	61	(0.4)
Pointe Coupee	129	(0.9)	127	(0.8)	131	(0.8)	117	(0.7)	126	(0.7)
Rapides	455	(3.2)	510	(3.3)	576	(3.6)	572	(3.6)	621	(3.7)
Red River	56	(0.4)	59	(0.4)	65	(0.4)	59	(0.4)	71	(0.4)
Richland	118	(0.8)	144	(0.9)	144	(0.9)	136	(0.8)	141	(0.8)
Sabine	136	(0.9)	94	(0.6)	108	(0.7)	94	(0.6)	141	(0.8)
St. Bernard	82	(0.6)	99	(0.6)	104	(0.6)	120	(0.7)	170	(1.0)
St. Charles	60	(0.4)	62	(0.4)	77	(0.5)	77	(0.5)	91	(0.5)
St. Helena	50	(0.3)	36	(0.2)	46	(0.3)	41	(0.3)	43	(0.3)
St. James	111	(0.8)	85	(0.5)	84	(0.5)	71	(0.4)	89	(0.5)
St. John	73	(0.5)	69	(0.4)	90	(0.6)	84	(0.5)	83	(0.5)
St. Landry	396	(2.7)	344	(2.2)	395	(2.4)	363	(2.3)	332	(2.0)
St. Martin	110	(0.8)	114	(0.7)	117	(0.7)	133	(0.8)	132	(0.8)
St. Mary	157	(1.1)	180	(1.2)	205	(1.3)	211	(1.3)	221	(1.3)
St. Tammany	214	(1.5)	225	(1.4)	247	(1.5)	300	(1.9)	309	(1.8)
Tangipahoa	312	(2.2)	346	(2.2)	355	(2.2)	337	(2.1)	374	(2.2)
Tensas	59	(0.4)	79	(0.5)	84	(0.5)	71	(0.4)	59	(0.3)
Terrebonne	169	(1.2)	213	(1.4)	210	(1.3)	191	(1.2)	243	(1.4)
Union	110	(0.8)	114	(0.7)	137	(0.8)	123	(0.8)	112	(0.7)
Vermilion	159	(1.1)	174	(1.1)	216	(1.3)	223	(1.4)	242	(1.4)
Vernon	112	(0.8)	119	(0.8)	110	(0.7)	111	(0.7)	118	(0.7)
Washington	229	(1.6)	228	(1.5)	226	(1.4)	222	(1.4)	259	(1.5)
Webster	204	(1.4)	209	(1.3)	244	(1.5)	253	(1.6)	236	(1.4)
W. Baton Rouge	71	(0.5)	76	(0.5)	74	(0.5)	59	(0.4)	76	(0.4)
W. Carroll	91	(0.6)	74	(0.5)	77	(0.5)	87	(0.5)	88	(0.5)
W. Feliciana	42	(0.3)	33	(0.2)	35	(0.2)	33	(0.2)	28	(0.2)
Winn	115	(0.8)	111	(0.7)	115	(0.7)	96	(0.6)	110	(0.7)
Total	14420	(100.0)	15528	(100.0)	16207	(100.0)	16018	(100.0)	16893	(100.0)

Table 4. — Comparison of deaths of persons 65 and over by sex, Louisiana, for selected years, 1962-1974*

Sex of Person Dying	1962		1965		1968		1971		1974	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
Male	7467	(51.8)	7992	(51.5)	8066	(49.8)	7957	(49.7)	8358	(49.5)
Female	6953	(48.2)	7536	(48.5)	8141	(50.2)	8061	(50.3)	8535	(50.5)
Total	14420	(100.0)	15528	(100.0)	16207	(100.0)	16018	(100.0)	16893	(100.0)

*Deaths from suicides, accidents, and homicides excluded.

Table 5. — Comparison of deaths of persons 65 and over by age groups, Louisiana, for selected years, 1962-1974*

Age-Group of Persons Dying	1962		1965		1968		1971		1974	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
65-72 Years of Age	5126	(35.5)	5550	(35.7)	5632	(34.8)	5528	(34.5)	5789	(34.3)
73-80 Years of Age	4889	(33.9)	5186	(33.4)	5483	(33.8)	5440	(34.0)	5541	(32.8)
81 Years of Age and Over	4405	(30.5)	4792	(30.9)	5092	(31.4)	5050	(31.5)	5563	(32.9)
Total	14420	(100.0)	15528	(100.0)	16207	(100.0)	16018	(100.0)	16893	(100.0)

*Deaths from suicides, accidents, and homicides excluded.

growth in population. Also, concentrations of deaths are, as expected, in the larger parishes. The data in Table 3 show that the relative number of deaths of those over 65 occurring in Jefferson, Caddo, and East Baton Rouge parishes increased somewhat through the years. However, in Orleans Parish an opposite trend occurred. This is probably a reflection of the redistribution of the state population.

Sex Distribution: From Table 4, it can be seen that there were slightly more male deaths than female deaths of persons 65 years of age or over in the state as a whole for the years 1962 and 1965 (51.8 and 51.5 percent, respectively). By contrast, in 1968, 1971, and 1974, there were slightly more female deaths than male deaths in this age group (50.2, 50.3, and 50.5 percent, respectively). It is logical to associate this reversal in pattern with the increasing number of women in the older ages. However, it is possible that other factors may be involved as well.

Age Distribution: Of the 14,420 deaths of persons 65 or over occurring in 1962, 35.5 percent were of persons 65 through 72 years of age, 33.9 percent of persons aged 73 through 80, and 30.5 percent of persons aged 81 or above. In 1965, 35.7 percent were in the youngest of the age groups, 33.4 percent in the middle group, and 30.9 percent in the oldest group. In 1968, the percentages for the three groups were: 34.8 percent, 33.8 percent, and 31.4 percent. In 1971, 34.5 percent of the deaths were of persons 65 through 72 years of age, 34.0 percent of persons 73 through 80 years of age, and 31.5 percent of persons 81 years or older. In 1974, 34.3 percent were in the lowest age group, 32.8 percent in the middle group, and 32.9 percent in the highest age group (see Table 5). It can be seen that there was a slight increase through the years in the percentage of persons dying after reaching 80. This trend signifies an increasing life span for all Louisianians.

Race Distribution: Table 6 shows the distribution of deaths of persons age 65 and over for the study years by race. Throughout the period, in keeping with their predominance in the population, whites recorded about twice as many deaths as blacks. The increasing percentage of white deaths most probably is explained in terms of the increasing life expectancy of blacks. For the U.S. as a whole, in 1962, the life expectancy of nonwhites was 64.1 years at birth, in 1974 it was 67 years. By contrast the life expectancy of whites in the U.S. only increased from 70.9 years to 72.7 years in this time period. It can be expected that Louisianians followed this same pattern.

Residence Distribution: As can be seen in Table 7, 41.3 percent of all the persons 65 years and over who died in 1962 lived in rural areas. This percentage dropped to 40.2 percent in 1965, increased slightly to 40.5 percent in 1968, dropped again slightly to 40.4 percent in 1971, and increased to 40.5 percent in 1974. All in all, the percentage of deaths in rural and urban areas remained fairly stable during the study period.

Table 6. — Comparison of deaths of persons 65 and over by race, Louisiana, for selected years, 1962-1974*

Race of Persons Dying	1962		1965		1968		1971		1974	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
White	9758	(67.7)	10579	(68.1)	11166	(68.9)	11212	(70.0)	12072	(71.5)
Black	4662	(32.3)	4949	(31.9)	5041	(31.1)	4806	(30.0)	4821	(28.5)
Total	14420	(100.0)	15528	(100.0)	16207	(100.0)	16018	(100.0)	16893	(100.0)

*Deaths from suicides, accidents, and homicides excluded.

Table 7. — Comparison of deaths of persons 65 and over by residence, Louisiana, for selected years, 1962-1974*

Residence of Persons Dying	1962		1965		1968		1971		1974	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
Rural	5951	(41.3)	6248	(40.2)	6562	(40.5)	6477	(40.4)	6838	(40.5)
Urban	8469	(58.7)	9280	(59.8)	9645	(59.5)	9541	(59.6)	10055	(59.5)
Total	14420	(100.0)	15528	(100.0)	16207	(100.0)	16018	(100.0)	16893	(100.0)

*Deaths from suicides, accidents, and homicides excluded.

The Comparative Mortality Index (CMI)

Total Population: Table 8 shows that the CMI for the total population aged 65 and over in 1965 (.99) reflects a slightly lower level of mortality in the state than in 1962. By contrast, the decline in mortality of persons 65 and over between 1962 and 1974 was quite noticeable, with the CMI dropping to .84. This finding is in contrast to the crude death rate level of this age-group but is a more accurate measure of mortality. The findings indicate that the longevity of Louisianians as a whole increased during the period 1962 to 1974 (also see Figure 1).

Rural Population: Table 8 also shows the CMI for the rural and urban populations of the state. Considering the rural population first, it can be seen that the CMI dropped somewhat from 1962 to 1974, but not as fast as for the total population. In fact, between 1971 and 1974 this index rose slightly. Why the rural CMI index showed less change than the CMI index for the total population is probably a matter of age structure. It will be seen later that the people living in rural parts of the state tend to live longer than urbanites once they reach age 65, and it is probable that this group is approaching an upper limit of longevity. At any rate, ruralites in the upper ages are adding to their present longevity at a slower rate than Louisianians in general in these ages.

Urban Population: Table 8 and Figure 1 show that the CMI for the urban component of the population over 65 years dropped quite noticeably (from 1.00 to .80) between 1962 and 1974. This indicates a distinct trend for persons in urban places to live longer once they reach 65. While such a trend is in keeping with recent national patterns, it is most encouraging to verify that urban Louisianians are sharing in this improvement. It may be that the gap between the life expectancy of all persons 65 and over will become smaller as life expectancy increases in urban areas.

Bivariate Analysis

To further test the hypothesis that the mortality of aged persons differed according to residence, and by sex and race, the death certificate data collected were subjected to a bivariate analysis. For each year studied, the

Table 8. — Comparative Mortality Index (CMI) by residence, for Louisianians 65 and over for selected years, 1962-1974*

Population	1962	1965	1968	1971	1974
Louisiana	1.00	.99	.96	.86	.84
Rural	1.00	.99	.98	.92	.93
Urban	1.00	.98	.92	.83	.80

*Deaths from suicides, accidents, and homicides excluded.

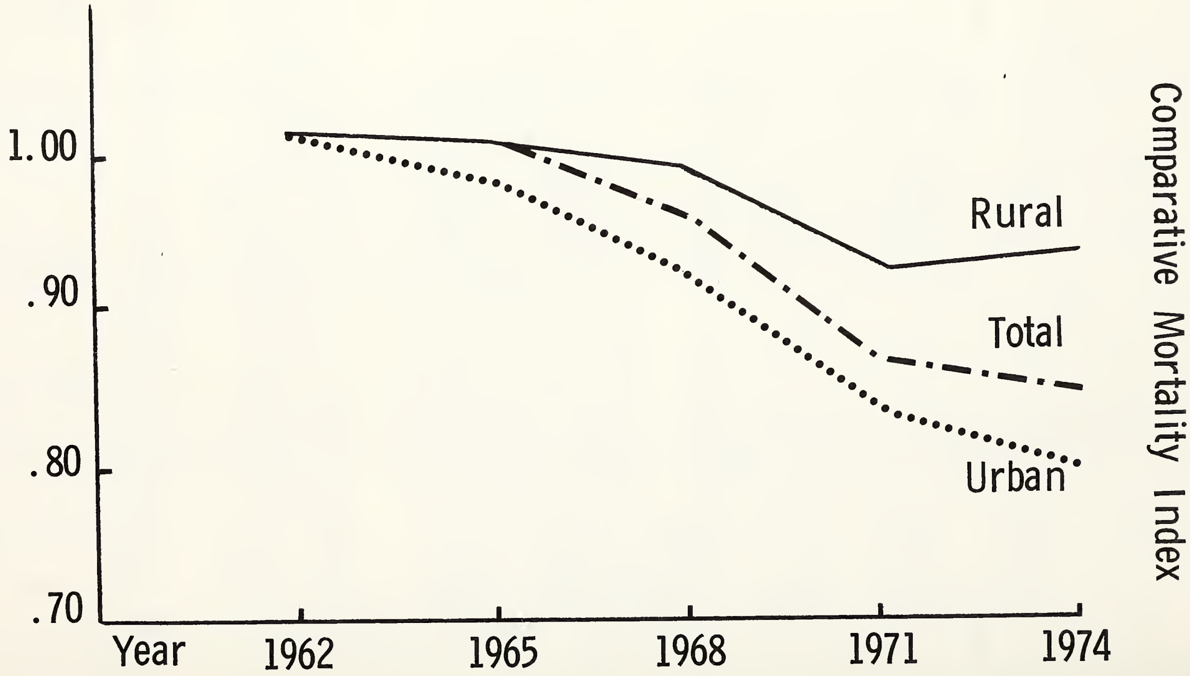

Figure 1—Comparative Mortality Index (CMI), by residence: Louisiana, 1962-1974.

total number of persons dying was divided into three age groups: 65-72 years, 73-80 years, and over 80 years. The percent of deaths of rural dwellers in each age group was computed. Further, the percent of rural and urban deaths by race and sex groups was determined. The findings from the analysis follow.

Residence, Race, and Sex: The major objective of this study was to determine if there were significant differences in longevity between urban and rural residents. The null hypothesis of no significant difference between rural and urban residence and mortality had to be rejected for all test years except 1974 on the basis of the findings. For all the years tested previous to 1974 there was a significant difference between rural and urban areas in the percentage of deaths in the age-group representing the three levels of longevity. This is to say, until 1974, a significantly larger percentage of rural dwellers than urban dwellers reached age 81 before dying. The data are presented in Table 9. Why this pattern changed in 1974 is not clear. However, as can be seen in Table 9, there is a trend for a larger percentage of urban dwellers to reach 80 years of age. The fact that the percentages of rural and urban dwellers over 65 dying at particular age levels have about equalized is an important discovery. It probably reflects trends toward an equalization of life expectancy. It is of significance that the trends in mortality shown by the bivariate comparisons made are similar to that shown by the CMI index computed. In the discussion which follows it will be seen that, although mortality differentials are disappearing between rural and urban residents, longevity differentials are still apparent.

Table 9. — Percentage distribution of deaths of Louisianians 65 and over, by level of longevity and residence for selected years, 1962-1974, with chi-square coefficients and level of significance of residential differences[1]

		Level of Longevity—Percent Dying				
Year	Residence	Low (65-72 Yrs.) %	Medium (73-80 Yrs.) %	High (81 and +) %	X^2	p level
1962	Rural	33.8	34.2	32.0	16.416*	< .001
	Urban	36.8	33.7	29.5		
1965	Rural	33.8	33.1	33.1	27.867*	< .001
	Urban	37.1	33.6	29.4		
1968	Rural	33.1	34.6	32.3	13.518*	< .01
	Urban	35.9	33.3	30.8		
1971	Rural	33.3	34.6	32.2	7.402*	< .05
	Urban	35.4	33.5	31.1		
1974	Rural	34.9	32.3	32.8	2.498*	< .30
	Urban	33.8	33.1	33.0		

[1] Suicides, accidents, and homicides excluded.
*with 2 d.f.

The next step in the analysis was to test for an association between age at death and sex and race. Findings (see Tables 10 and 11) show that there were important differences between the various population groups. As can be seen, mortality rate was significantly associated with sex and race among the Louisiana aged population in every sample year studied.

Race characteristics of the persons over 65 dying during the study years followed commonly reported patterns. Table 10 shows that the black aged had a larger percentage dying in the 65-72 year group than the white aged for each of the years studied. The reverse is true for the two older age groups. Clearly more whites than blacks tend to survive to be 81 years of age or over.

Table 11 shows the findings regarding age at death, by sex, in summary form. Again, it is keeping with common patterns that a larger percentage of women survived to the older ages.

Race and Sex by Residence: The frequency tables computed for bivariate analysis made it possible to determine trends in the age distribution of deaths. When the focus of attention is on the percentage changes in deaths which occurred over the study years in one particular race or sex group with place of residence held constant, the following patterns emerge (see Tables 12 and 13).

From 1962 to 1974, the percentage of both rural and urban blacks surviving to age 80 before dying increased perceptibly. Although the change in this direction was not as great for rural blacks as for urban blacks, the former continued to have a considerably larger percent of their members survive beyond 80 years (30.7 percent vs. 26.6 percent in 1974).

Table 10. — Percentage distribution of deaths of Louisianians 65 and over, by level of longevity and race for selected years, 1962-1974, with chi-square coefficients and level of significance of race differences[1]

		Level of Longevity—Percent Dying				
Year	Race Residence	Low (65-72 Yrs.) %	Medium (73-80 Yrs.) %	High (81 and +) %	X^2	p level
1962	White	31.7	34.3	34.0	243.02*	.001
	Black	43.6	33.1	23.3		
1965	White	32.2	34.0	33.8	219.34*	.001
	Black	43.4	32.2	24.4		
1968	White	31.5	34.6	33.9	186.80*	.001
	Black	42.0	32.1	25.9		
1971	White	31.9	34.3	33.8	133.87*	.001
	Black	40.5	33.2	26.3		
1974	White	32.5	32.6	34.9	88.81*	.001
	Black	38.7	33.3	28.0		

[1] Suicides, accidents, and homicides excluded.
*with 2 d.f.

Table 11. — Percentage distribution of deaths of Louisianians 65 and over, by level of longevity and sex, for selected years, 1962-1974, with chi-square coefficients and level of significance of sex differences[1]

Year	Sex [redacted]	Level of Longevity—Percent Dying Low (65-72 Yrs.) %	 Medium (73-80 Yrs.) %	 High (81 and +) %	X^2	p level
1962	Male	40.3	33.9	25.8	246.96*	< .001
	Female	30.5	33.9	35.6		
1965	Male	40.7	33.4	25.9	247.05*	< .001
	Female	30.4	33.4	36.2		
1968	Male	40.2	33.9	25.9	328.04*	< .001
	Female	29.3	33.7	37.0		
1971	Male	40.5	34.5	25.0	377.77*	< .001
	Female	28.6	33.5	37.9		
1974	Male	41.3	33.3	25.4	546.74*	< .001
	Female	27.3	32.4	40.3		

[1] Suicides, accidents, and homicides excluded.
*with 2 d.f.

Table 12. — Percentage distribution of deaths of Louisianians 65 and over, by race, residence, and longevity, for selected years, 1962-1974

Year	Residence	Race	Level of Longevity (Percent of Persons Dying) Low (65-72 Years) %	 Medium (73-80 Years) %	 High (81 Years and Over) %
1962	Rural	White	30.2	34.8	34.9
		Black	40.8	32.8	26.3
	Urban	White	32.7	33.9	33.4
		Black	45.6	33.4	21.0
1965	Rural	White	31.3	34.1	34.6
		Black	39.2	31.2	29.7
	Urban	White	32.8	33.9	33.3
		Black	46.1	32.8	21.1
1968	Rural	White	31.4	35.4	33.1
		Black	36.8	32.8	30.3
	Urban	White	31.5	34.0	34.4
		Black	45.3	31.6	23.1
1971	Rural	White	32.1	34.4	33.5
		Black	36.4	35.0	28.6
	Urban	White	31.8	34.2	33.9
		Black	43.0	32.1	24.9
1974	Rural	White	34.5	32.0	33.4
		Black	36.2	33.1	30.7
	Urban	White	31.0	33.0	36.0
		Black	39.9	33.5	26.6

In contrast to urban blacks, the percent of urban whites surviving to 80 increased faster than their counterparts in rural areas from 1962 to 1974. In fact, a larger percentage of urban whites survived to age 80 than of all other race-residence groups.

When the sex of those persons who died after reaching age 65 is controlled by residence, the picture evolving during the study period is again revealing. Rural males, apparently, were not surviving beyond 80 in as great a relative number in 1974 as they were in 1962. By contrast, a larger percentage of rural females were living beyond 80 in 1974. Shifting to the urban setting, a slightly larger percentage of urban males were surviving beyond 80 in 1974, but a considerably larger percentage of urban females were living beyond 80.

The conclusions which appear most interesting from the above analysis are: (1) that all blacks are living longer and that rural blacks have a longevity advantage over urban blacks; (2) that females continue to increase their longevity advantage over males, with urban females apparently catching up to rural females in terms of their relative numbers surviving beyond 80 years of age.

Table 13. — Percentage distribution of deaths of Louisianians 65 and over, by sex, and residence, and longevity, for selected years, 1962-1974

Year	Residence	Sex [redacted]	Level of Longevity (Percent of Persons Dying) Low (65-72 Years)	Medium (73-80 Years)	High (81 Years and Over)
1962	Rural	Male	37.3	34.1	28.3
		Female	29.3	34.2	36.5
	Urban	Male	42.6	33.8	23.6
		Female	31.3	33.6	35.1
1965	Rural	Male	37.3	33.7	29.0
		Female	29.7	32.4	37.9
	Urban	Male	43.3	33.1	23.6
		Female	30.9	34.0	35.0
1968	Rural	Male	37.1	34.6	28.3
		Female	28.5	34.6	26.9
	Urban	Male	42.7	33.4	24.0
		Female	29.8	33.2	37.0
1971	Rural	Male	38.4	35.4	26.2
		Female	27.6	33.6	38.8
	Urban	Male	42.1	33.7	24.2
		Female	29.2	33.4	37.4
1974	Rural	Male	40.9	32.6	26.5
		Female	28.3	31.9	39.8
	Urban	Male	41.7	33.7	24.6
		Female	26.8	32.6	40.6

Longevity Characteristics of Persons Aged 65 and Over

The General Index of Longevity (GIL)

Total Population: The pattern which emerged when a GIL was computed for the Louisiana population as a whole is shown in Table 14. From 1962 to 1974, this index increased gradually in that the percent of persons 80 years of age and over increased from 1.15 percent of the population in 1962 to 1.60 percent in 1974. This trend is in keeping with the pattern demonstrated by the CMI. Without a doubt, there is an increasing number of persons 80 years of age and over in the state. This may be partially explained by a decreasing birth rate, but it still emphasizes a decided trend toward greater longevity in the state.

Rural Population: The GIL for Louisiana's rural population, interestingly, grew at a faster rate than that for the state as a whole. The percentage of persons over 80 years of age in the rural population increased from 1.42 percent in 1962 to 2.77 percent in 1974. Such a gain leaves no doubt that the rural population of the state is including an increasing number of persons over 80. In fact, for every 100 rural persons in the state there is now an average of almost three persons over 80 years of age, and this number is increasing at a fairly rapid rate. This growth is no doubt associated with a decreasing birth rate in rural areas as well as in the state as a whole. It could also be associated with an increasing out-migration of younger persons and an in-migration of older persons. From 1965 to 1970, there was a net out-migration of about 5000 persons aged 20 to 29 years while in the 65 years-of-age-and-over class, some 964 more persons came into the state than left the state (U.S. Department of Commerce, Current Population Reports, May, 1977). Nevertheless, there is still strong evidence that persons in rural areas were living longer in 1974 than in 1962.

Urban Population: The GIL increased for the urban dwellers of Louisiana from 0.99 percent in 1962 to 1.02 percent in 1974. Comparatively speaking, it can be seen that longevity for rural Louisianians, as measured by the GIL, increased by 1.35 percent, but by only 0.45 percent for all Louisianians and a mere 0.03 percent for urban Louisianians. Why a larger percentage of rural people than urban people in the state tended to

Table 14. — General Index of Longevity (GIL) by residence, Louisiana population, for selected years, 1962-1974

	1962	1965	1968	1971	1974
Louisiana	1.15	1.25	1.35	1.49	1.60
Rural	1.42	1.77	2.11	2.44	2.77
Urban	0.99	0.97	0.97	1.01	1.02

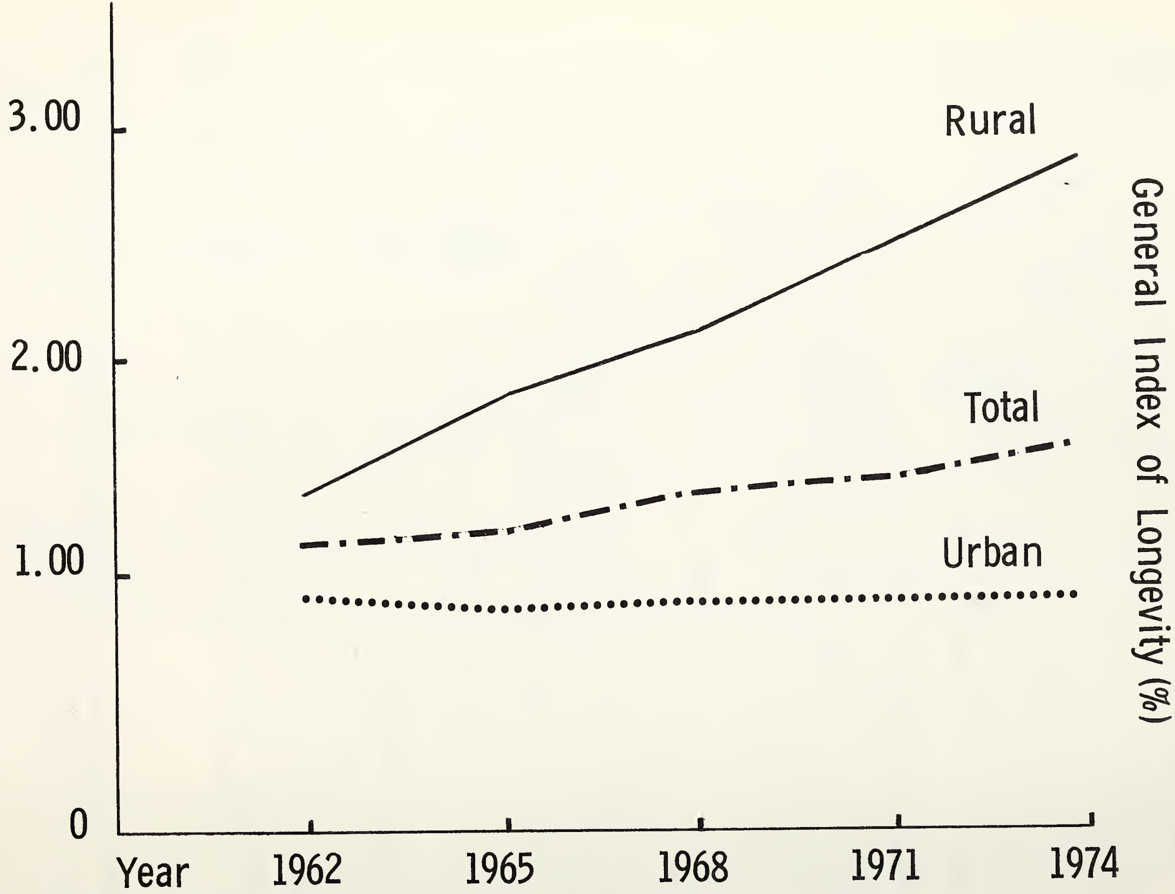

Figure 2—General Index of Longevity (GIL), by residence, Louisiana, 1962-1974.

live beyond 80 years of age is difficult to answer. There have been slight shifts in the composition of the population, but this phenomenon cannot be totally accounted for in terms of changing population composition, that is, the trend toward urbanization in the state. Figure 2 shows how these comparative trends look in graphic format.

The Level of Longevity of the Elderly (LLE)

Total Population: Table 15 shows the LLE index for the total population of Louisiana, the rural Louisiana population, and the urban Louisiana population. For the total population, the LLE increased gradually from 1962 (10.56 percent) to 1974 (12.26 percent). This indicates an increasing percentage of persons over 80 years of age among the population aged 60 and over. It is a strong indicator that the people of the state are tending to live longer than in previous years, since the changing birth rate does not affect this index in the short run.

Rural Population: For the rural Louisiana population, the LLE shows a phenomenal increase for the period of study, which was just over a decade. In 1962, persons over 80 years of age made up 12.46 percent of all persons living in rural areas 60 years of age or over. By 1974, this percentage had increased to 20.80 percent. In other words, one out of five persons in the over 60 age group was at least 80 years old. This trend indicates a higher survival rate in recent years in rural areas. It may be that migration of older persons to rural areas accounts in part for this fact, but recent urban to rural migration trends in Louisiana do not appear greater than they were a decade ago.

Urban Population: An LLE index pattern different from that for the rural population exists for the urban population of Louisiana. Among city dwellers the trend is toward a decreasing rather than an increasing LLE index. In 1962, 9.42 percent of the persons 60 years and over in urban areas were 80 years of age or more. However, in 1974 only 7.90 percent of the total aged population was as old as 80 years. This finding suggests that the urban population 80 years or more, in comparison with the rural population 80 years or more, are making up a smaller percentage of the population

Table 15. — Level of Longevity of the Elderly (LLE) by residence, Louisiana population, for selected years, 1962-1974

	1962	1965	1968	1971	1974
Louisiana	10.56	11.09	11.54	11.92	12.26
Rural	12.46	14.85	17.02	18.99	20.80
Urban	9.42	8.93	8.53	8.19	7.90

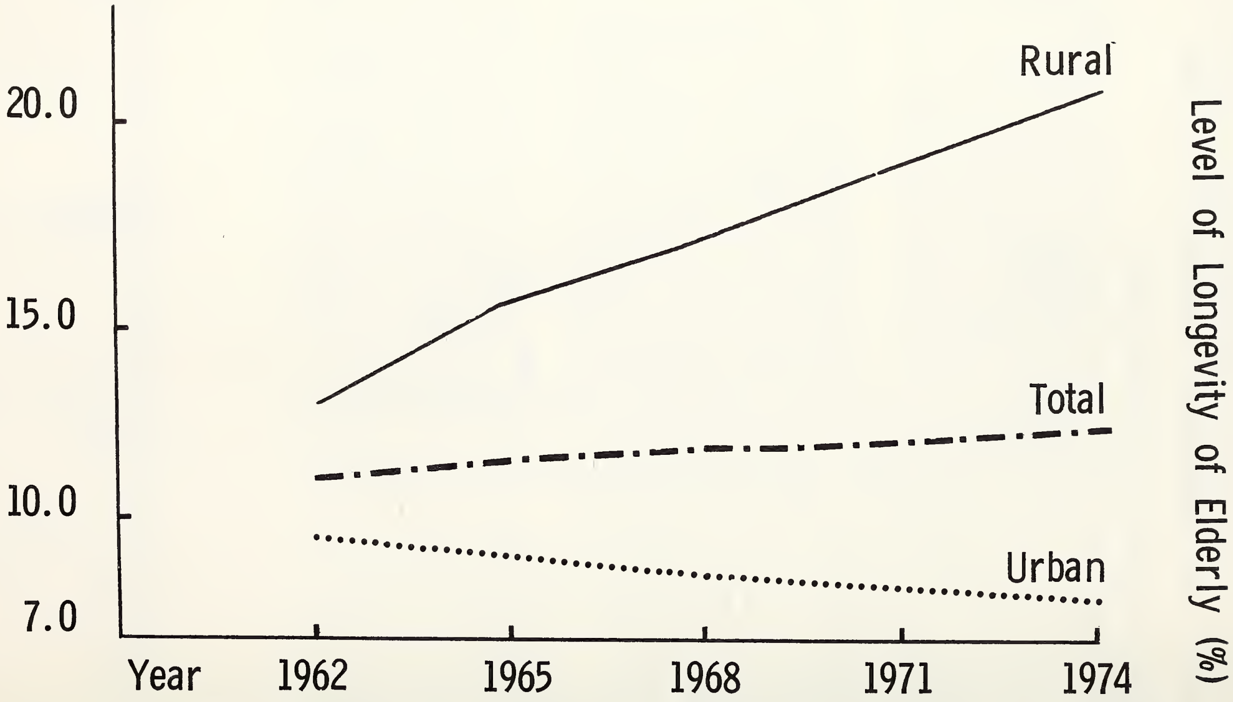

Figure 3—Level of Longevity of Elderly (LLE), by residence, Louisiana, 1962-1974.

over 60. Figure 3 and Table 15 show the LLE indexes computed. Of course, as noted, it is known that older people migrate to rural areas from city areas, but the trends shown by the LLE indexes are too divergent to be accounted for totally in this manner. The fact of greater longevity in rural areas appears to be clearly substantiated.

Summary and Implications

It was noted in the introduction to this study that modern medical science has long had as its central goal the maintenance of a healthy and long-lived population.Research efforts have especially focused on diseases and physical incapacities with the result that acute illness and death have been significantly reduced. However, studies of longevity have made it clear that certain social factors are related to how long people live. This fact set the stage for the present study, which was especially concerned with the relationship of residence to survival after becoming aged — that is after reaching 65. The specific findings of the study may be summarized as follows:

1. The death rate of persons in Louisiana over 65 years of age tends to be distributed in the same manner as the population. However, from 1972 to 1974, a slight increase in the overall death rate of persons dying from non-violent causes can be noted. This increase is especially pronounced among persons living in urban places and suggests greater longevity for persons in rural areas, once they reach 65.
2. Using a Comparative Mortality Index (CMI) as a measure, it is clear that Louisianians 65 years and over experienced a noticeable increase in longevity from 1962-1974, despite the slight rise in the crude death rate. Persons living in both rural and urban areas enjoyed this increase, although urbanites tended to show more relative improvement. This is probably because ruralites are older, on the average, than urbanites.
3. A bivariate analysis shows a) that females aged 65 and over had longer life expectancy than males of this age for each of the years in the test period — this finding is consistent with the conclusion of previous research on sex differentials in longevity; and b) that white Louisianians reaching 65 generally lived longer than black Louisianians in this age group. This discovery is also in line with previous research findings.
4. A frequency analysis of persons dying after the age of 80 shows relatively more blacks, females, and urbanites reaching 80 in 1974 than in 1962.
5. The General Index of Longevity (GIL) definitely confirms that Louisianans tended to live longer in 1974 than in 1962 and that rural Louisianians had a substantial longevity advantage over urban Louisianians as measured by the number of people 80 years or older relative to the total population.

6. The Level of Longevity of the Elderly (LLE) index also definitely indicates an increase in longevity from 1962 to 1974 for older Louisianians and especially for rural Louisianians. The percent of 80-year-olds among those 60 years or over is definitely increasing, but especially among ruralites.

Overall, for the period 1962-1974, the findings of this study of the survival rate of persons 65 years of age and over can be put succinctly as follows: (1) that both rural and urban Louisianians aged 65 and over tend to live longer now than in the past; (2) that rural Louisianians had a substantial advantage in longevity throughout the period 1962-1974 over urban Louisianians; (3) that females lived longer than males; and (4) that whites lived longer than blacks.

The above findings provide further evidence that residence as well as sex and race has a pronounced effect on longevity, once a person becomes aged. This conclusion highlights the importance of one's environment for longevity. The nature of rural-urban environmental difference has been investigated by several researchers. Youmans (1967:113-115), studied the disengagement of elderly men in three areas of life—economic activities, family relationships, and leisure-time activities—and concluded (1) that decline in economic status occurred more sharply with age in urban settings than in the rural areas; (2) that urban men evidenced somewhat stronger feelings of rejection by their families than did rural men, a finding which probably reflected the greater prevalence of family cohesion in rural areas; and (3) that rural males had stronger informal attachments to other persons in their community than was true of urban males, in effect had more enjoyable leisure-time experiences.

The implication of the findings of studies such as Youmans and of this study is that the environment in rural areas is more conducive to long life. This environment includes among other things a continuation of work and community roles without abrupt change, closer family ties and relationships, and more continuity in and opportunity for friends and acquaintances. It also may be that the physical environment of rural areas is more healthful. The opportunity for exercise and for experiencing low levels of pollution is probably greater.

For whatever reason, rural life and living apparently increases longevity in Louisiana, at least after the age of 65, and many studies show this increase cannot be attributed to availability of better health care or to greater affluence. This finding has significance both for further study of social factors and longevity and for social planning relative to the aged in the state and the nation.

Literature Cited

Barclay, G. W.
1958 Techniques of Population Analysis. New York: John Wiley & Sons, Inc.
Blalock, H. M.
1972 Social Statistics. New York: McGraw-Hill.
Bouvier, L. F.
1973 "The Demography of Aging," in Aging: Its Challenge to the Individual and to Society, ed. William C. Bier. New York: Fordham University Press, pp. 39-46.
Cole, W. E.
1958 Urban Society. Boston: The Riverside Press.
Dodge, David and W. Martin
1971 Social Stress and Chronic Illness. Notre Dame: Notre Dame Press.
Leaf, A.
1973 "Every Day Is a Gift when You Are Over 100," National Geographic, January 1973, pp. 93-119.
Leonard, W. M.
1976 Basic Social Statistics. New York: West Publishing Co.
New York Times Magazine
1971 "Why They Live to Be 100, or Even Older, In Abkhasia," New York Times Magazine, December 26, 1971, pp. 3, 28-34.
Newsweek
1977 "How Long Will I Live?" Newsweek, January 3, 1977, pp. 6-7.
1977 "The Graying of America," Newsweek, January 23, 1977, pp. 50-65.
Palmore, E.
1971 "The Promise and Problems of Longevity Studies," in Prediction of Life Span, ed. E. Palmore and F. Jeffers. Lexington, Ma.: D. C. Heath Co., pp. 3-12.
Rao, S. L. N.
1973 "On Long-Term Mortality Trends in the United States, 1850-1968," Demography 10:405.
Riley, M. W., M. Johnson and A. Foner
1972 Aging and Society, Vol. III, A Sociology of Age Stratification. New York: Russel Sage Foundation.
Rose, C.
1971 "Critique of Longevity Studies," in Prediction of Life Span, ed. E. Palmore and F. Jeffers. Lexington, Ma.: D. C. Heath Co., pp. 13-29.
Rosenfeld, A.
1976 "The 'Fixed' Life-Span of Humans Is Neither Absolute Nor Immutable—We May Learn to Live for Centuries," Smithsonian 7:40-46.
Sachuk, N. N.
1970 "Population Longevity Study: Sources and Indices," Journal of Gerontology 25:262-264.
Sheldon, H. D.
1960 "The Changing Demographic Profile," in Handbook of Social Gerontology, ed. Clark Tibbitts. Chicago: University of Chicago Press, pp. 27-61.
Shryock, H. S. and J. S. Siegel
1973 The Methods and Materials of Demography, U.S. Bureau of the Census, Vol. 2. Washington, D.C.: U.S. Government Printing Office.

Siegel, J. S. and W. E. O'Leary

1973 "Some Demographic Aspects of Aging in the U.S.," Current Population Reports. Washington, D.C.: U.S. Government Printing Office, Series P-23, Number 43.

Sobel, H.

1966 "The Control of Longevity," The Gerontologist 6:132-136.

Stockwell, E.

1973 "Changing Age Composition of the American Population," Social Biology 19:3-5.

Strehler, B. L.

1971 "Genetic and Cellular Aspects of Life Span Prediction," in Prediction of Life Span, ed. E. Palmore and F. Jeffers. Lexington, Ma.: D. C. Heath Co., pp. 33-50.

Tibbitts, C.

1960 Handbook of Social Gerontology. Chicago: University of Chicago Press.

U. S. Bureau of the Census

1973 Census of Population: 1970, Vol. I, Characteristics of the Population, Part 1, United States Summary—Section 2, Washington, D.C.: U.S. Government Printing Office, Appendix A, pp. 4-6.

U.S. Census Office

1902 Abstract of the Twelfth Census of the United States, 1900. Table 50. Washington, D.C., Government Printing Office.

U.S. Department of Commerce Bureau of the Census

1977 Gross Migration by County: 1965-1970. Series P-25, NO. 701, Population Estimates and Projections, Current Population Reports, pp. 54-55.

U.S. News and World Report

1976 "Next 25 Years—How Your Life Will Change," U.S. News and World Report 80:39-42, March 22, 1976.

1976 "How To Enjoy A Longer Life," U.S. News and World Report 81:29-32, July 12, 1976.

1976 "How To Eat And Live Longer," U.S. News and World Report 81:37-40, August 9, 1976.

1976 "As U.S. Death Rate Hits Historic Low," U.S. News and World Report 81:47, August 23, 1976.

Youmans, E. G.

1967 Older Rural Americans: A Sociological Perspective. Lexington: University of Kentucky Press.

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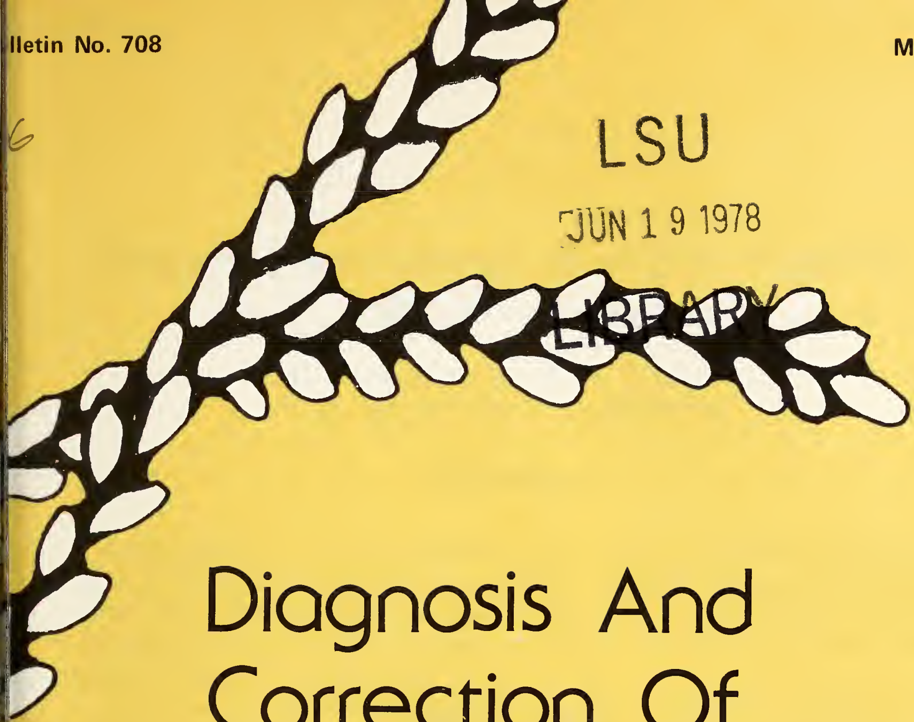

Diagnosis And Correction Of Zinc Problems In Rice Production

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Acknowledgment

Appreciation is expressed to Mr. M. D. Faulkner, Superintendent, and other personnel of the Rice Experiment Station for their support and cooperation in this project.

Diagnosis and Correction of Zinc Problems in Rice Production

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Introduction

Investigations of different aspects of the zinc (Zn) nutrition of the rice plant have been in progress for 11 years in Louisiana. Research conducted under field conditions indicates that Zn deficiency in rice grown on soils of the coastal prairies in the southwestern area of the state is associated with certain soil and climatic conditions.

Soil reaction, or the pH value of the soil, apparently has the most important influence on Zn availability. It has been noted that a one-unit rise in soil reaction, from pH 5.3 to 6.3, drastically reduced the solubility and uptake of Zn by the rice plant.

Soil-test summaries indicate that approximately 15 per cent of the surface soils in the rice area in their natural condition are neutral to alkaline in reaction. The pH values of other soils have been increased by applications of limestone or by repeated use of irrigation water from wells or other sources that contain appreciable amounts of Na, Ca, and Mg salts.

Since Zn is less available as the pH of the soil approaches neutrality, soils used for the production of rice should be kept moderately acid. In most soils, Zn should be readily available at a pH of about 5.5.

An investigation was initiated in 1968 and continued through 1974 to determine the effects of five rates of Zn on the yield of rice (*Oryza sativa* L.) and on the chemical composition of the soil and the leaves of rice plants grown on Crowley silt loam (Typic Albaqualf) with an initial pH greater than 7.5. Due to an infestation of red rice, the experimental area was fallow-plowed in 1972, and yield data were not obtained for that year.

In 1971 the experiment was included as a contribution to Project S-80, ''Diagnosis and Correction of Zinc Problems in Crop Production.'' Only the results obtained in 1971, 1973, and 1974 are included in this publication.

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Experimental Procedure

Several years prior to the initiation of the investigation, the experimental site was water leveled, and a maximum cut of 6 inches was made to facilitate drainage and the application of flood water. Limestone was also added to create an alkaline pH to increase the response to Zn.

The experimental design was a randomized block with four replications of each of five rates of Zn. The plot size was 7 feet x 50 feet.

The Zn was applied at 0, 3, 6, 12, and 24 pounds per acre. The source of Zn was $ZnSO_4 \cdot H_2O$, 36 percent Zn. Equivalent amounts of S as Na_2SO_4 were added to each plot to insure that all plots received the same amounts of S. Zn was broadcast on the soil surface in an aqueous solution immediately before planting. The Zn treatments were applied in 1968, 1969, and 1971.

Each plot received a uniform annual application of 120 pounds of N, 22 pounds of P, and 42 pounds of K per acre; the fertilizer sources were urea, 46 percent N; concentrated superphosphate, 20.2 percent P; and muriate of potash, 50 percent K. The fertilizer was applied with a drill at planting.

Saturn rice was planted in 1971 and Vista was planted in 1973 and 1974. The rice cultivars were planted with a drill at a seeding rate of 90 pounds per acre. Each plot consisted of 12 drill rows spaced 7 inches apart.

Soil samples were collected annually from each plot prior to the application of the plant nutrient elements. The soil samples were air-dried at room temperature, ground to pass a 2-mm stainless steel sieve, and stored in 16-ounce plastic bags. The soil samples were analyzed by state soil testing laboratories in Florida, Virginia, and Kentucky.

Tissue samples were collected annually from the plants on each of the plots. The tissue samples consisted of 100 mature leaves taken when the rice panicle was approximately 2 mm long. The leaves were rinsed in distilled water, placed in cotton bags, and dried in a forced draft oven at 67°C for 12 hours. The dried leaves were ground in a stainless steel Wiley mill to pass a 20-mesh sieve and stored in 8-ounce plastic bags. The plant tissue samples were analyzed by laboratories at the University of Georgia and Texas A&M University.

The yield, plant tissue, and soil chemical analyses data were evaluated using analyses of variance (randomized block design) and correlation analyses.

Results and Discussion

Treatment means for the rice yield and plant and soil chemical analyses by year and for all years combined are presented in Tables 1 through 4. The analyses of variance are presented in Tables 5 and 6. The data show that a highly significant response in yield was obtained from the application of

Table 1.—Treatment means for rice yield and plant and soil chemical analyses (1971)

	Zn treatment, lbs./acre				
	0	3	6	12	24
Yield, lbs./acre	2322.30	3244.25	3133.50	3340.25	3691.00
PLANT ANALYSIS					
Ga. P, %	0.16	0.17	0.17	0.18	0.17
Ga. K, %	1.69	1.68	1.48	1.63	1.39
Ga. Ca, %	0.14	0.13	0.12	0.12	0.11
Ga. Mg, %	0.15	0.14	0.13	0.13	0.11
Ga. Mn, ppm	275.50	259.50	223.00	213.75	199.25
Ga. Fe, ppm	51.50	47.00	43.25	44.25	44.25
Ga. B, ppm	4.00	6.00	5.25	6.00	5.50
Ga. Cu, ppm	7.75	8.00	9.00	8.25	7.75
Ga. Zn, ppm	14.25	15.50	17.00	16.00	23.25
Ga. Al, ppm	26.50	26.00	23.50	21.25	24.00
Ga. Mo, ppm	2.53	2.63	2.43	2.40	2.68
Ga. Sr, ppm	8.50	7.25	6.50	6.75	7.75
Ga. Ba, ppm	39.00	36.50	32.50	33.00	28.00
Ga. Na, ppm	872.00	689.25	655.00	543.50	712.75
Tex. Zn, ppm	9.63	12.75	11.00	12.63	11.75
SOIL ANALYSIS					
Fla. Zn[1], ppm	1.93	2.25	2.85	3.60	6.05
Fla. Zn[2], ppm	1.50	1.85	2.45	2.95	5.13
Fla. Zn[3], ppm	0.73	0.90	1.13	1.43	2.28
Va. pH	7.73	7.70	7.63	7.65	7.73
Va. O.M., %	0.98	1.00	0.90	0.70	0.78
Va. Ca, lbs./acre	2344.00	2344.00	2344.00	2344.00	2344.00
Va. Mg, lbs./acre	239.00	239.00	239.00	239.00	239.00
Va. P, lbs./acre	6.00	6.50	5.75	5.75	5.00
Va. K, lbs./acre	76.50	81.50	76.50	74.00	79.00
Ky. pH	7.50	7.15	7.08	7.33	7.33
Ky. Ca, lbs./acre	——	——	——	——	——
Ky. Mg, lbs./acre	——	——	——	——	——
Ky. P, lbs./acre	4.30	4.00	4.00	4.00	4.00
Ky. K, lbs./acre	105.30	110.00	110.00	106.00	82.30

[1] 0.1 *N* HCl

[2] 0.05 *N* HCl in 0.025 *N* H_2SO_4

[3] DTPA-TEA

Table 2.—Treatment means for rice yield and plant and soil chemical analyses (1973)

	Zn treatment, lbs./acre				
	0	3	6	12	24
Yield, lbs./acre	3784.50	3880.50	4016.50	3875.75	3904.25
PLANT ANALYSIS					
Ga. P, %	0.20	0.19	0.19	0.17	0.19
Ga. K, %	1.90	1.57	1.69	1.72	1.90
Ga. Ca, %	0.16	0.13	0.13	0.13	0.14
Ga. Mg, %	0.18	0.14	0.14	0.11	0.14
Ga. Mn, ppm	150.25	128.25	140.00	121.25	133.00
Ga. Fe, ppm	85.50	81.75	80.25	75.75	137.00
Ga. B, ppm	9.25	10.00	10.00	8.75	9.75
Ga. Cu, ppm	9.75	6.00	6.00	4.50	8.75
Ga. Zn, ppm	19.00	20.75	25.25	20.75	27.50
Ga. Al, ppm	86.50	81.00	65.50	63.25	75.00
Ga. Mo, ppm	1.03	1.58	1.43	1.33	1.38
Ga. Sr, ppm	11.50	8.50	7.75	9.75	9.25
Ga. Ba, ppm	6.50	4.25	4.25	4.00	4.50
Ga. Na, ppm	342.00	289.50	339.50	268.50	338.00
Tex. Zn, ppm	19.03	17.78	20.90	27.25	28.28
SOIL ANALYSIS					
Fla. Zn[1], ppm	2.23	2.70	3.13	4.30	6.85
Fla. Zn[2], ppm	1.88	2.13	2.55	3.45	5.38
Fla. Zn[3], ppm	0.90	0.95	1.00	1.55	2.55
Va. pH	7.28	7.45	7.25	7.30	7.28
Va. O.M., %	0.90	1.00	0.90	0.70	0.78
Va. Ca, lbs./acre	2167.30	2251.50	2128.50	2089.00	2310.00
Va. Mg, lbs./acre	240.00	240.00	240.00	240.00	240.00
Va. P, lbs./acre	4.30	5.80	8.50	6.30	4.30
Va. K, lbs./acre	52.00	48.50	54.50	51.50	50.00
Ky. pH	7.60	7.30	7.40	7.30	7.50
Ky. Ca, lbs./acre	1840.00	1930.00	1847.50	1862.50	1892.50
Ky. Mg, lbs./acre	596.30	683.50	631.00	617.30	665.00
Ky. P, lbs./acre	3.00	3.50	3.80	3.80	3.00
Ky. K, lbs./acre	90.00	98.80	99.80	100.00	100.80

[1] 0.1 N HCl [2] 0.05 N HCl in 0.025 N H_2SO_4 [3] DTPA-TEA

Table 3.—Treatment means for rice yield and plant and soil chemical analyses (1974)

	Zn treatment, lbs./acre				
	0	3	6	12	24
Yield, lbs./acre	4754.50	4354.50	4892.75	5128.50	4977.75
PLANT ANALYSIS					
Ga. P, %	0.17	0.15	0.16	0.17	0.16
Ga. K, %	2.09	1.96	1.90	2.08	2.02
Ga. Ca, %	0.15	0.13	0.13	0.15	0.13
Ga. Mg, %	0.15	0.13	0.13	0.14	0.12
Ga. Mn, ppm	384.50	335.25	333.50	383.75	339.25
Ga. Fe, ppm	44.50	39.25	40.75	45.75	44.25
Ga. B, ppm	4.00	3.75	3.75	4.00	4.00
Ga. Cu, ppm	2.50	2.25	2.00	2.75	2.25
Ga. Zn, ppm	13.50	13.75	14.25	16.25	16.75
Ga. Al, ppm	13.50	12.75	13.25	14.75	12.00
Ga. Mo, ppm	2.20	2.10	1.95	2.13	2.18
Ga. Sr, ppm	7.25	7.00	6.50	6.75	6.50
Ga. Ba, ppm	10.25	8.25	7.50	9.25	7.50
Ga. Na, ppm	123.25	131.75	99.25	98.25	140.00
Tex. Zn, ppm	17.00	17.25	19.88	20.63	18.25
SOIL ANALYSIS					
Fla. Zn[1], ppm	1.27	2.41	1.48	2.26	1.93
Fla. Zn[2], ppm	0.84	1.91	1.00	1.97	1.57
Fla. Zn[3], ppm	0.41	1.05	0.52	1.03	0.88
Va. pH	7.43	7.63	7.55	7.50	7.55
Va. O.M., %	0.73	0.70	0.93	1.03	1.08
Va. Ca, lbs./acre	2358.00	2338.30	2328.50	2358.00	2333.50
Va. Mg, lbs./acre	239.00	239.00	239.00	239.00	239.00
Va. P, lbs./acre	3.50	3.00	4.30	3.80	2.80
Va. K, lbs./acre	56.00	50.00	38.00	50.50	38.50
Ky. pH	7.80	7.80	7.70	7.60	7.60
Ky. Ca, lbs./acre	1817.50	1820.00	1805.00	1792.50	1822.50
Ky. Mg, lbs./acre	513.00	537.00	518.30	507.00	568.50
Ky. P, lbs./acre	5.50	6.30	7.30	6.80	6.50
Ky. K, lbs./acre	102.80	99.00	100.30	102.50	100.00

[1] 0.1 *N* HCl   [2] 0.05 *N* HCl in 0.025 *N* H_2SO_4 [3] DTPA-TEA

Table 4.—Treatment means for rice yield and plant and soil chemical analyses (three year averages)

	Zn treatment, lbs./acre				
	0	3	6	12	24
Yield, lbs./acre	3620.42	3826.42	4014.25	4114.83	4191.00
PLANT ANALYSIS					
Ga. P, %	0.18	0.17	0.18	0.17	0.17
Ga. K, %	1.89	1.73	1.69	1.81	1.77
Ga. Ca, %	0.15	0.13	0.13	0.13	0.12
Ga. Mg, %	0.16	0.14	0.13	0.12	0.12
Ga. Mn, ppm	270.08	241.00	232.17	239.58	223.83
Ge. Fe, ppm	60.50	56.00	54.75	55.25	75.17
Ga. B, ppm	5.75	6.58	6.33	6.25	6.42
Ga. Cu, ppm	6.67	5.42	5.67	5.17	6.25
Ga. Zn, ppm	15.58	16.67	18.83	17.67	22.50
Ga. Al, ppm	42.17	39.92	34.08	33.08	37.00
Ga. Mo, ppm	1.92	2.10	1.93	1.95	2.08
Ga. Sr, ppm	9.08	7.58	6.92	7.75	7.83
Ga. Ba, ppm	18.58	16.33	14.75	15.42	13.33
Ga. Na, ppm	445.75	370.17	364.58	303.42	396.92
Tex. Zn, ppm	15.22	15.93	17.26	20.17	19.43
SOIL ANALYSIS					
Fla. Zn[1], ppm	1.81	2.45	2.49	3.39	4.94
Fla. Zn[2], ppm	1.41	1.96	2.00	2.79	4.03
Fla. Zn[3], ppm	0.68	0.97	088	1.34	1.90
Va. pH	7.48	7.59	7.48	7.48	7.52
Va. O.M., %	0.87	0.90	0.91	0.81	0.88
Va. Ca, lbs./acre	2289.75	2311.25	2267.00	2263.67	2329.17
Va. Mg, lbs./acre	239.33	239.33	239.33	239.33	239.33
Va. P, lbs./acre	4.58	5.08	6.17	5.25	4.00
Va. K, lbs./acre	61.50	60.00	56.33	58.67	55.83
Ky. pH	7.62	7.42	7.40	7.42	7.45
Ky. Ca, lbs./acre	1828.75	1875.00	1826.25	1827.50	1857.50
Ky. Mg, lbs./acre	554.63	610.25	574.63	562.13	616.75
Ky. P, lbs./acre	4.25	4.58	5.00	4.83	4.50
Ky. K, lbs./acre	99.33	102.58	103.33	102.83	94.33

[1] 0.1 *N* HCl [2] 0.05 *N* HCl in 0.025 *N* H_2SO_4 [3] DTPA-TEA

Zn. When the data for the three years were combined, it was found that yields were increased at all levels of applied Zn. A per-acre increase of 206, 394, 494, and 571 pounds of rough rice resulted from the application of 3, 6, 12, and 24 pounds of Zn per acre, respectively.

As expected, levels of plant tissue Zn generally increased as the level of applied Zn was increased. The Texas and Georgia values for plant Zn were in rather close agreement ($r = 0.336$, $P < 0.01$, Table 7). The data in Table 4 indicate that a Zn concentration of approximately 15 ppm in rice leaf tissue is below the levels where highest yields were obtained. The means presented in Table 4 indicate that the Mn concentration in the leaves decreased as the rate of applied Zn was increased. A highly significant negative correlation ($r = -0.482$) was obtained between the concentration of Zn and Mn in the leaf tissue (Table 7).

The data in Table 4 show that the application of the different rates of Zn resulted in increases in the level of soil-test Zn determined by the three methods of extraction. Higher quantities of Zn were extracted with 0.1 *N* HCl than with 0.05 *N* HCl in 0.025 *N* H_2SO_4 or with DTPA-TEA. The data show that approximately 1.8 ppm of Zn extracted with 0.1 *N* HCl was a marginal level of Zn in Crowley silt loam for the economical production of rice. Corresponding values of 1.4 ppm and 0.7 ppm of Zn extracted with 0.05 *N* HCl in 0.025 *N* H_2SO_4, and with DTPA-TEA, respectively, were also considered to be marginal levels for rice. The data in Table 8 show that highly significant positive correlations were obtained for the three methods used for extracting soil Zn. Highly significant positive correlation coefficients were also obtained between the yield of rice and the three methods of extracting Zn from the soil.

Deficiency symptoms attributed to low levels of Zn in the tissue were observed visually on rice plants growing on plots that did not receive an application of Zn. In early stages of growth the symptoms appeared as a sudden blighting of the oldest leaves of the seedling. The lesions were surrounded by chlorotic areas which became white. The lesions and chlorotic areas extended from the sheath up the midrib of the oldest true leaf, parallel to the leaf veins. As the disorder developed, the base of the leaf blade and mid-vein became bleached with brown flecks, spots, and irregular linear blotches. The affected leaves rapidly became blighted and the seedlings appeared to be dead. However, when the blighted outer leaves were removed, the youngest leaf remained green. Cool, overcast weather contributed to the symptoms, and extended periods of adverse weather together with a high infestation of rice water weevils increased the intensity of the visually observed deficiency symptoms.

Zinc deficiency symptoms often are not expressed until the permanent flood is applied to a field. Initially the lower leaves of affected plants become limp and float on the surface of the flood water. These leaves

Table 5.—Analysis of variance for rice yield and plant analyses by the Georgia and Texas laboratories (three years combined)[1]

Source of variation	d.f.	Yield	Georgia							
			P	K	Ca	Mg	Mn	Fe	B	Cu
Year	2	14089955.7**	0.002962**	0.961665**	0.001552	0.000602	244305.717**	15138.82**	172.2167**	188.6167**
Rep/year	9	203322.5	0.000512*	0.077559**	0.001434*	0.001339	978.789	211.79	2.8556	2.7889
Treatment	4	639659.6**	0.000054	0.070968*	0.001064	0.002848**	3660.042*	887.54	1.1833	4.5417
Treatment x year	8	378695.8*	0.000312	0.052567*	0.000233	0.000443	1871.467	881.13	1.3833	7.8667
Error	36	160529.8	0.000225	0.022094	0.000590	0.000719	1018.525	440.62	2.7167	5.1917

Table 5.—(Continued)

Source of variation	d.f.	Yield	Georgia						Texas
			Zn	Al	Mo	Sr	Ba	Na	Zn
Year	2	14089955.7**	316.850**	21140.00**	7.2195**	36.017**	4997.32**	1714086.67**	630.55**
Rep/year	9	203322.5	25.728	129.03	0.1428	6.078	52.97*	13376.16	18.23
Treatment	4	639659.6**	85.083*	176.21	0.0882	7.417	45.89*	32205.42*	55.56*
Treatment x year	8	378695.8*	12.183	119.71	0.0855	1.829	17.13	15066.60	27.04
Error	36	160529.8	22.561	98.60	0.1858	4.314	14.97	9953.20	16.74

[1] Mean squares are reported. *Denotes a significant difference at 5%. **Denotes a significant difference at 1%.

rapidly turn yellow-orange and develop small brown flecks. In the more severely affected areas of fields or in deep water, seedlings begin to disappear below the surface of the flood water, the rice stand thins, and areas of open water appear. Plants that do not die under deficiency conditions are often stunted and have brown flecks on the leaf blades. These flecks expand into irregular, linear, purple-brown blotches on the older leaves. If the affected plants have responded to an application of N fertilizer before the ''bronzing'' symptoms are expressed, a distinctive chlorotic area which rapidly becomes white is often observed in the mid-leaf area and around the brown blotches. The leaf blade or tip of the blade may become bronze in color due to the formation and coalescence of many small purple-brown flecks. From a distance the plants in a field take on a bronze to gold color. Often plants in the affected field exhibit typical N deficiency symptoms as well as those typical of ''bronzing.'' Zinc deficiency appears to interfere with the normal utilization of N.

Plants can exhibit Zn deficiency symptoms at any stage of growth. If plants become deficient at heading, the leaves and glumes will show the typical chlorosis, brown flecking, and spotting. When Zn deficiency becomes severe at heading, the florets are affected. A condition similar to straight-head may occur where the panicles of affected plants remain upright as fertilization fails to take place or kernel development is aborted.

The data presented indicate that the concentration of Fe in the plant tissue was relatively low at all levels of applied Zn. Preliminary investigations have indicated that Fe deficiency can be expected when the level of Fe in rice leaves at the tillering stage of plant development falls below 70 ppm. The Zn treatments had no significant influence on the level of Fe in the rice leaves. The low levels of Fe found in the tissue may have been due to the low solubility of Fe in the Crowley silt loam at pH values of 7.5.

The B contents of the rice-leaf tissue at all of the levels of applied Zn varied from 5.8 ppm to 6.6 ppm (Table 4). These values for B are higher than the critically low value of 3.5 ppm that has been established for rice plants.

The data also indicate that the Cu content of the rice leaves at all of the levels of applied Zn was relatively low. Copper deficiency in rice may be expected when the concentration of Cu in rice leaves is below 6 ppm. A significant response to application of Cu was obtained on a Crowley silt loam at another location prior to the initiation of the current investigation.

Many other correlations among the variables measured proved to be significant, indicating that additional research is needed on the role of the macro- and micronutrient elements in the nutrition of rice plants.

Table 6.—Analysis of variance for rice yield and soil analyses by the Florida, Virginia and Kentucky laboratories (three years combined)[1]

Source of variation	d.f.	Yield	Florida			Virginia				
			0.1 N HCl	0.05 N HCl in 0.025 N NH_2SO_4	DTPA-TEA Zn	pH	Organic matter	Ca	P	K
Year	2	14089955.7**	1522.85**	903.71**	275.254**	0.7102**	0.0062	158880.42**	36.82**	5544.47**
Rep/year	9	203322.5	3.65	4.65*	3.138**	0.0144	0.0202	24683.86	1.57	76.84
Treatment	4	639659.6**	59.63**	58.90*	17.691**	0.0296	0.0186	9553.88**	7.81*	69.23
Treatment x year	8	378695.8*	30.42**	32.05*	10.088**	0.0131	0.1103**	11949.56	3.55	119.13
Error	36	160529.8	3.36	1.70	0.618	0.0170	0.0175	6528.41	3.27	49.57

Table 6.—(Continued)

Source of variation	d.f.	Yield	Kentucky		
			pH	P	K
Year	2	14089955.7**	0.8645**	51.62**	120.22
Rep/year	9	203322.5	0.0261	0.43	194.73
Treatment	4	639659.6**	0.0960**	1.03	171.60
Treatment x year	8	378695.8*	0.0501	0.64	230.24
Error	36	160529.8	0.0299	1.21	217.99

Source of variation	d.f.	Kentucky	
		Ca	Mg
Year	1	39690.00**	120670.23**
Rep/year	6	31911.67**	8016.16**
Treatment	4	3916.25	6380.79**
Treatment x year	4	2183.75	1118.79
Error	24	4686.67	1426.05

[1] Mean squares are reported. *Denotes a significant difference at 5%. **Denotes a significant difference at 1%.

Table 7.—Simple correlation coefficients (r) for rice yield and plant and soil analyses (all years combined)

		Plant analyses														
		Georgia														Texas
	Yield	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo	Sr	Ba	Na	Zn
Yield	1.000	-0.089	0.546**	0.117	-0.110	0.406**	-0.075	-0.151	-0.571**	-0.006	-0.213	-0.169	-0.193	-0.638**	-0.824**	0.446**
PLANT ANALYSES																
Ga. P	-0.089	1.000	0.115	0.328*	0.569**	-0.359**	0.530**	0.615**	0.503**	0.528**	0.654**	-0.199	0.301*	-0.135	0.073	0.245
Ga. K	0.546**	0.115	1.000	0.612**	0.378**	0.566**	0.059	-0.158	-0.354**	-0.062	-0.078	-0.117	0.132	-0.325*	-0.540**	0.320*
Ga. Ca	0.117	0.328*	0.612**	1.000	0.680**	0.242	0.198	0.008	0.049	-0.046	0.280*	-0.176	0.507**	-0.073	-0.108	0.110
Ga. Mg	-0.110	0.569**	0.378**	0.680**	1.000	0.134	0.212	0.124	0.354**	0.041	0.375**	-0.253*	0.417**	0.014	0.092	-0.029
Ga. Mn	0.407**	-0.359**	0.566**	0.241	0.134	1.000	-0.537**	-0.740**	-0.495**	-0.482**	-0.737**	0.449**	-0.331**	0.143	-0.276*	-0.224
Ga. Fe	-0.075	0.530**	0.059	0.198	0.212	-0.537**	1.000	0.673**	0.426**	0.556**	0.743**	-0.446**	0.324*	-0.349**	-0.047	0.463**
Ga. B	-0.150	0.615**	-0.158	0.008	0.124	-0.740**	0.673**	1.000	0.410**	0.582**	0.813**	-0.417**	0.183	-0.277*	0.017	0.384**
Ga. Cu	-0.571**	0.503**	-0.354**	0.049	0.354**	-0.495**	0.426**	0.410**	1.000	0.307*	0.467**	-0.130	0.343**	0.418**	0.628**	-0.186
Ga. Zn	-0.006	0.528**	-0.062	-0.046	0.041	-0.482**	0.556**	0.582**	0.307*	1.000	0.521**	-0.265*	0.050	-0.171	-0.001	0.336**
Ga. Al	-0.213	0.654**	-0.078	0.280*	0.375**	-0.737**	0.743**	0.813**	0.467**	0.521**	1.000	-0.628**	0.546**	-0.371**	0.029	0.420**
Ga. Mo	-0.169	-0.199	-0.177	-0.176	-0.253*	0.449**	-0.446*	-0.417**	-0.130	-0.265*	-0.628**	1.000	-0.508**	0.601**	0.365**	-0.575**
Ga. Sr	-0.193	0.301*	0.132	0.507**	0.417**	-0.331**	0.324*	0.183	0.343**	0.050	0.546**	-0.508**	1.000	-0.146	0.123	0.183
Ga. Ba	-0.638**	-0.135	-0.325*	-0.073	0.014	0.143	-0.349**	-0.349*	0.418**	-0.171	-0.371**	0.601**	-0.146	1.000	0.776**	-0.676**
Ga. Na	-0.824**	0.073	-0.540**	-0.108	0.092	-0.276*	-0.047	0.017	0.628**	-0.001	0.029	0.365**	0.123	0.776**	1.000	-0.518**
Texas Zn	0.446**	0.245	0.320*	0.110	-0.029	-0.224	0.463**	0.384**	-0.186	0.336**	0.420**	-0.575**	0.183	-0.676**	-0.518**	1.000
SOIL ANALYSES																
Fla. Zn[1]	0.713**	-0.381**	0.587**	0.118	-0.086	0.713**	-0.298*	-0.515**	0.649**	-0.275*	-0.526**	0.112	0.253*	-0.375**	-0.648**	0.164
Fla. Zn[2]	0.691**	-0.372**	0.552**	0.102	-0.106	0.684**	0.290*	-0.502**	-0.616**	-0.257*	-0.509**	0.106	-0.243	-0.355**	-0.618**	0.149
Fla. Zn[3]	0.665**	-0.359**	0.562**	0.132	-0.082	0.678**	-0.291*	-0.499**	-0.598**	-0.268*	-0.503**	0.107	-0.219	-0.336**	-0.599**	0.125
Va. pH	-0.292*	-0.380**	-0.241	-0.197	-0.130	0.358**	-0.555**	-0.537**	0.007	-0.365**	-0.585**	0.579**	-0.269*	0.615**	0.417**	-0.611**
Va. O.M.	0.100	0.106	0.026	0.056	0.213	0.116	-0.019	-0.039	0.145	-0.094	0.001	-0.009	-0.074	-0.017	0.046	-0.072
Va. Ca	-0.022	-0.287*	-0.049	-0.127	-0.005	0.415**	-0.270*	-0.434**	-0.018	-0.283*	-0.500**	0.395**	-0.300*	0.328*	0.123	-0.456**
Va. Mg	-0.052	0.494**	-0.066	0.140	0.145	-0.779**	0.717**	0.818**	0.247	0.524**	0.919**	-0.735**	0.460**	-0.565**	-0.163	0.557**
Va. P	-0.401**	0.352**	-0.332**	-0.069	0.033	-0.368**	0.122	0.427**	0.373**	0.355**	0.342**	0.023	0.048	0.230	0.330**	0.042
Va. K	-0.672**	-0.004	-0.492**	-0.153	-0.012	-0.117	-0.225	-0.100	0.447**	0.027	-0.175	0.503**	-0.097	0.799**	0.780**	-0.544**
Ky. pH	0.403**	-0.147	0.539**	0.200	0.204	0.436**	-0.037	-0.208	-0.500**	-0.152	-0.163	-0.114	0.028	-0.403**	-0.516**	0.171
Ky. Ca	-0.374*	0.207	-0.276	-0.050	0.147	-0.353*	0.372*	0.382*	0.349*	0.259	0.335*	-0.224	0.166	-0.372*	0.392*	0.048
Ky. Mg	-0.684**	0.397*	-0.472**	-0.136	0.090	-0.741**	0.585**	0.729**	0.532**	0.600**	0.682**	-0.414**	0.306	-0.648**	0.783**	0.165
Ky. P	0.545**	-0.220	0.491**	0.110	-0.179	0.757**	-0.407**	-0.515**	-0.558**	-0.305*	-0.533**	0.295*	-0.344**	-0.142	-0.448**	0.104
Ky. K	-0.043	0.796	0.100	0.050	0.011	0.137	-0.082	-0.047	-0.016	0.089	-0.121	0.155	-0.011	0.163	0.033	-0.053

[1] 0.1 *N* HCl. [2] 0.05 *N* HCl in 0.025 *N* H_2SO_4. [3] DPTA-TEA.

*Denotes a significant difference at 5%.

**Denotes a significant difference at 1 %.

Table 8.—Simple correlation coefficients (r) for rice yield and plant and soil analyses (all years combined)

		Florida			Virginia						Kentucky				
		0.1 *N* HCl	0.025 *N* H_2SO_4	DTPA-TEA											
	Yield	Zn	Zn	Zn	pH	Organic matter	Ca	Mg	P	K	pH	Ca	Mg	P	K
Yield	1.000	0.713**	0.691**	0.665**	-0.292*	0.100	-0.022	-0.052	-0.401**	-0.672**	0.403**	-0.374*	-0.684**	0.545**	-0.043
PLANT ANALYSES															
Ga. P	-0.089	-0.381**	-0.372**	-0.359**	-0.380**	0.106	-0.287*	0.494**	0.352**	-0.004	-0.147	0.207	0.397*	-0.220	0.080
Ga. K	0.546**	0.587**	0.552**	0.562**	-0.241	0.026	-0.049	-0.066	-0.332**	-0.492**	0.539**	-0.276	-0.472**	0.491**	0.100
Ga. Ca	0.117	0.118	0.102	0.132	-0.197	0.056	-0.127	0.140	-0.069	-0.153	0.200	-0.050	-0.136	0.110	0.049
Ga. Mg	-0.110	-0.086	-0.106	-0.082	-0.130	0.213	-0.005	0.145	0.033	-0.012	0.204	0.147	0.090	-0.018	0.011
Ga. Mn	0.407**	0.713**	0.684**	0.678**	0.358**	0.116	0.415**	-0.779**	-0.368**	-0.117	0.436**	-0.353*	-0.741**	0.757**	0.137
Ga. Fe	-0.075	-0.298*	-0.290*	-0.291*	-0.555**	-0.019	-0.270*	-0.717**	0.122	-0.225	-0.037	0.372*	0.585**	-0.407**	-0.082
Ga. B	-0.150	-0.515**	-0.502**	-0.499**	-0.537**	-0.039	-0.434**	0.818**	0.427**	-0.100	-0.208	0.382*	0.729**	-0.515**	-0.047
Ga. Cu	-0.571**	-0.649**	-0.616**	-0.598**	0.007	0.145	-0.018	0.247	0.373**	0.447**	-0.500**	0.349*	0.532**	-0.558**	-0.016
Ga. Zn	-0.006	-0.275*	-0.257*	-0.268*	-0.365**	-0.094	-0.283*	0.524**	0.355**	0.027	-0.152	0.259	0.600**	-0.305*	0.089
Ga. Al	-0.213	-0.526**	-0.509**	-0.503**	-0.585**	0.001	-0.500**	0.919**	0.342**	-0.175	-0.163	0.335*	0.682**	-0.533**	-0.121
Ga. Mo	-0.169	0.112	0.106	0.107	0.579**	-0.009	0.395**	-0.735**	0.023	0.503**	-0.114	-0.224	-0.414**	0.295*	0.155
Ga. Sr	-0.193	-0.253*	-0.243	-0.219	-0.269*	-0.074	-0.300*	0.460**	0.048	-0.097	0.028	0.166	0.306	-0.344**	-0.011
Ga. Ba	-0.638**	-0.375**	-0.355**	-0.336**	0.615**	-0.017	0.328*	-0.565**	0.230	0.799**	-0.403**	-0.372*	-0.648**	-0.142	0.163
Ga. Na	-0.824**	-0.648**	-0.618**	-0.599**	0.417**	0.046	0.123	-0.163	0.330**	0.780**	-0.516**	0.392*	0.783**	-0.448**	0.033
Texas Zn	0.446**	0.164	0.149	0.125	-0.611**	-0.072	-0.456**	0.557**	0.042	-0.544**	0.171	0.048	0.165	0.104	-0.053
SOIL ANALYSES															
Fla. Zn[1]	0.713**	1.000	0.982**	0.973**	0.085	0.046	0.275*	-0.432**	-0.535**	-0.504**	0.579**	-0.292	-0.597**	0.708**	-0.043
Fla. Zn[2]	0.691**	0.982**	1.000	0.992**	0.091	0.052	0.261*	-0.417**	-0.526**	-0.488**	0.523**	-0.305	-0.571**	0.623**	-0.051
Fla. Zn[3]	0.665**	0.973**	0.992**	1.000	0.119	0.058	0.256*	-0.418**	-0.514**	-0.500**	0.527**	-0.316*	-0.565**	0.677**	-0.055
Va. pH	-0.292*	0.085	0.091	0.119	1.000	0.094	0.493**	-0.703**	-0.175	0.486**	-0.023	0.064	-0.230	0.142	0.071
Va. O.M.	0.100	0.046	0.052	0.058	0.094	1.000	0.176	-0.068	-0.040	-0.067	-0.141	0.207	0.083	0.147	0.012
Va. Ca	-0.022	0.275*	0.261*	0.256*	0.493**	0.176	1.000	-0.591**	-0.350**	0.262*	0.145	0.354*	-0.069	0.178	0.218
Va. Mg	-0.052	-0.432**	-0.417**	-0.418**	-0.703**	-0.068	-0.591**	1.000	0.264*	-0.323*	-0.112	0.328*	0.720**	-0.534**	-0.130
Va. P	-0.401*	-0.535**	-0.526**	-0.514**	-0.175	-0.040	-0.350**	0.264*	1.000	0.318*	-0.363**	0.048	0.229	-0.086	0.129
Va. K	-0.672**	-0.504**	-0.488**	-0.500**	0.486**	-0.067	0.262*	-0.323*	0.318*	1.000	-0.412**	0.387*	0.300	-0.355**	0.195
Ky. pH	0.403**	0.579**	0.523**	0.527**	-0.023	-0.141	0.145	-0.112	-0.363**	-0.412**	1.000	0.024	-0.294	0.405**	-0.079
Ky. Ca	-0.374*	-0.292	-0.305	-0.316*	0.064	0.207	0.354*	0.328*	0.048	0.387*	0.024	1.000	0.727**	-0.330*	0.528**
Ky. Mg	-0.684**	-0.597**	-0.571**	-0.565**	-0.230	0.083	-0.069	0.720**	0.229	0.300	-0.294	0.727**	1.000	-0.647**	0.228
Ky. P	0.545**	0.708**	0.673**	0.677**	0.142	0.147	0.178	-0.534**	-0.086	-0.355**	0.405**	-0.330*	-0.647**	1.000	0.057
Ky. K	-0.043	-0.043	-0.051	-0.055	0.071	0.012	0.218	-0.130	0.129	0.195	-0.079	0.528**	0.228	0.057	1.000

[1] 0.1 *N* HCl. [2] 0.05 *N* HCl in 0.025 *N* H_2SO_4. [3] DPTA-TEA.

*Denotes a significant difference at 5%.

**Denotes a significant difference at 1 %.

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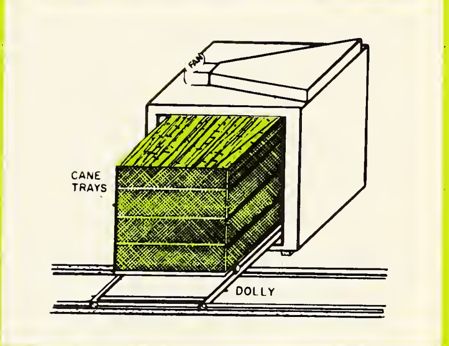

Aerated Steam: A System for Heat Treating Sugarcane to Control Ratoon Stunting Disease

Billy J. Cochran, Mansel M. Mayeux and René J. Steib

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Center for Agricultural Sciences
And Rural Development

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AERATED STEAM: A SYSTEM FOR HEAT TREATING SUGARCANE TO CONTROL RATOON STUNTING DISEASE

Billy J. Cochran, Mansel M. Mayeaux, and René J. Steib*

Introduction

The ability to control diseases in seeds and plants by heat is well documented. A combination of a prescribed treatment and time of exposure is used to inactivate or control ratoon stunting disease in sugarcane. Hot air and hot water are two media currently used for treating sugarcane seed pieces for a specified time and at a prescribed temperature without severly reducing the viability of the seed pieces. The hot water treatment, developed in Australia, consists of immersing seed cane in water at a temperature of 50°C for 3 hours. The hot air system developed for Louisiana utilizes a recirculating electrically heated air system with the cane seed pieces being exposed to an entering air temperature of 58°C for 8 hours.

Both the hot air and hot water treatment methods recommend the seed pieces be shucked or cleaned before treatment. A small fluctuation in the treatment temperature affects germination and the extent of disease control. Hot or cold spots within the treatment chamber also affect germination and disease control. The advantages and disadvantages of both systems contributed to the development of a system for treating sugarcane seed pieces using aerated steam.

The Aerated Steam System

Aerated steam is defined as a mixture of air and steam. A constant amount of air conditioned to a predetermined temperature with steam is recirculated until the system reaches thermal equilibrium. Circulation is continued with the addition of steam to maintain the prescribed temperature for a specific length of time. An aerated steam system utilizes the efficiency and uniformity of heat transfer through a moist environment as well as the flexibility of a recirculating air system. A schematic of the pilot system is shown in Figure 1. It consists of (1) a treating chamber, (2) a recirculating air system, (3) a steam generator, and (4) a method of controlling the amount of steam applied to the system. Recirculation at a rate of approximately eight times the empty volume of the treatment chamber per minute is adequate to minimize the blast effect of higher velocities and also suspend the steam within the turbulent air throughout the chamber.

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Components and assembly sequence for the steam system are shown in Figure 2. The steam can be generated with a portable steam generator with a rated capacity of 100 gallons per hour. Steam from the generator is stored in an accumulator where the generator pressure pulses are cushioned. The accumulator collects condensate and other foreign materials from the steam and discharges it through a steam trap. Although the system operates at 30 psi of steam pressure, the accumulator should be rated at a minimum of 150 psi and have a capacity of approximately 50 gallons. Steam going to the system is taken from the top of the accumulator and passed through a modulating steam flow control valve. The amount of steam injected into the recirculating air system to maintain a prescribed temperature is controlled by the steam control valve. A temperature sensing element is placed near the entrance transition to monitor the temperature of the aerated steam entering the treatment chamber. The sensing element temperature is indicated by a dial thermometer on the control valve. The prescribed temperature is set by manually adjusting the spring pressure on the pilot of the steam control valve. Steam passing through the valve is distributed into the air stream through a nozzle constructed of galvanized pipe with 1/16 inch holes spaced 1 inch apart. The nozzle should be positioned horizontally across the air duct between the fan and the entrance transition with the steam emission holes facing opposite to the direction of air flow. Turbulence within the system will thoroughly mix the air and steam to provide a humid environment at the prescribed temperature for treating the seed pieces.

Research Results

Copper constantan thermocouples were used in conjunction with a 24-point continuously recording potentiometer to monitor the rate of heat transfer from the aerated steam into the cane stalks as well as to indicate the temperature equilibrium within the treatment chamber. The thermocouples were strategically placed in the center of cane stalks, attached to the outside of cane stalks, and placed at various locations throughout the cane mat within the chamber. Recording the temperature also showed the temperature variation within the system and the relative temperature of each

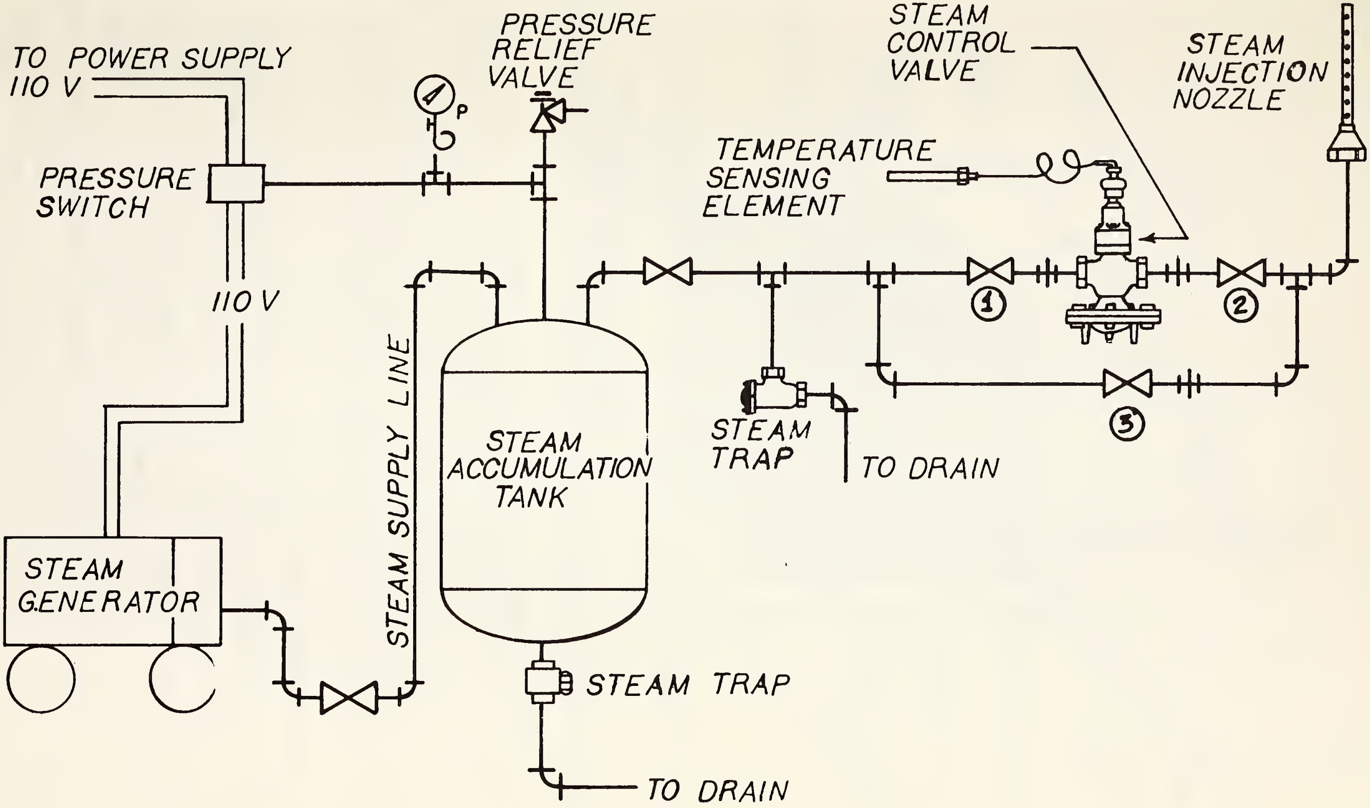

Figure 1.—A circuit diagram of an aerated steam system

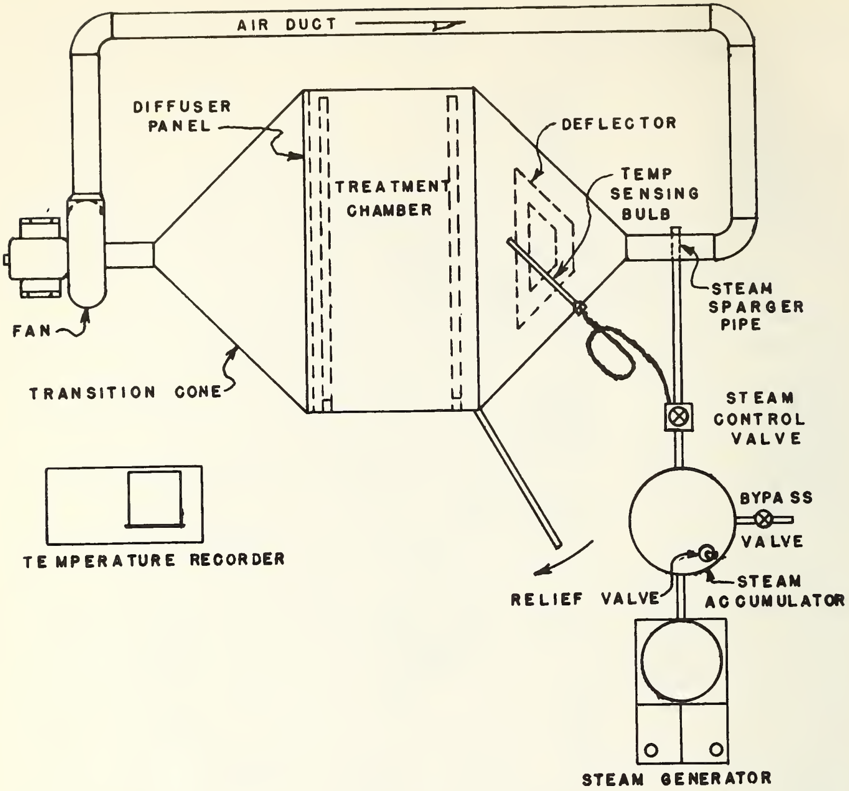

Figure 2.—Schematic diagram of aerated steam heat treating system components

thermocouple location at a given time.

The cane stalks were stripped of trash and stacked on racks similar to those used with hot air systems. Results showed temperature equilibrium and distribution within the treatment chamber was maintained at the desired temperature, ± 1°C, with aerated steam. The temperature of all thermocouples positioned in the system was in equilibrium within 1 hour after treatment began. Similar results were obtained when the stalks were not stripped of the leaves.

After the aerated steam system was tested using an experimental treatment chamber (Figure 2) and the operation parameters established, a full-scale treatment system was designed. The unit shown in Figure 3 is capable of treating approximately 1 ton of sugarcane stalks with adhering trash and leaves. The inside dimensions of the chamber are 6 feet x 8 feet x 8 feet. The cane is stacked into a cart on removable pipes or trays. The layer thickness should be 15 inches with a 3-inch space between layers to assure circulation throughout the chamber. Aerated steam distribution within the chamber is accomplished with a fan displacing a minimum of 2,500 cubic feet of air per minute. Openings from the entrance plenum to the treatment

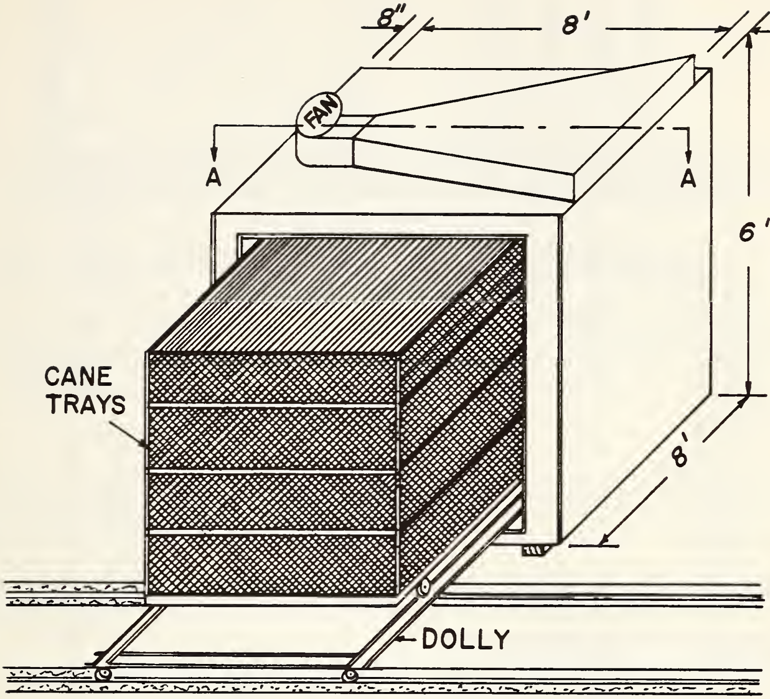

Figure 3.—The aerated steam system

chamber are of various sizes to provide an even distribution of air from top to bottom, and the outlet plenum is slotted in a similar manner (see Figure 4).

During the first hour of treatment, steam must be provided at a rate sufficient to overcome heat loss and to raise the temperature of approximately 1 ton of cane with leaves from about 15°C to 53°C. The specific heat of sugarcane has been found to be 0.94 Btu/lb-°F. Based on this value the process was calculated to require 188,752 Btu to increase the temperature of a ton of cane to 53°C. The time for the treatment chamber to reach the prescribed treatment temperature is affected by the initial air-cane temperature when the aerated steam is turned on. Time-temperature data for each layer tested was recorded and analyzed to obtain a relationship between the change in temperature inside the treatment chamber and time. This relationship was plotted for each layer thickness.

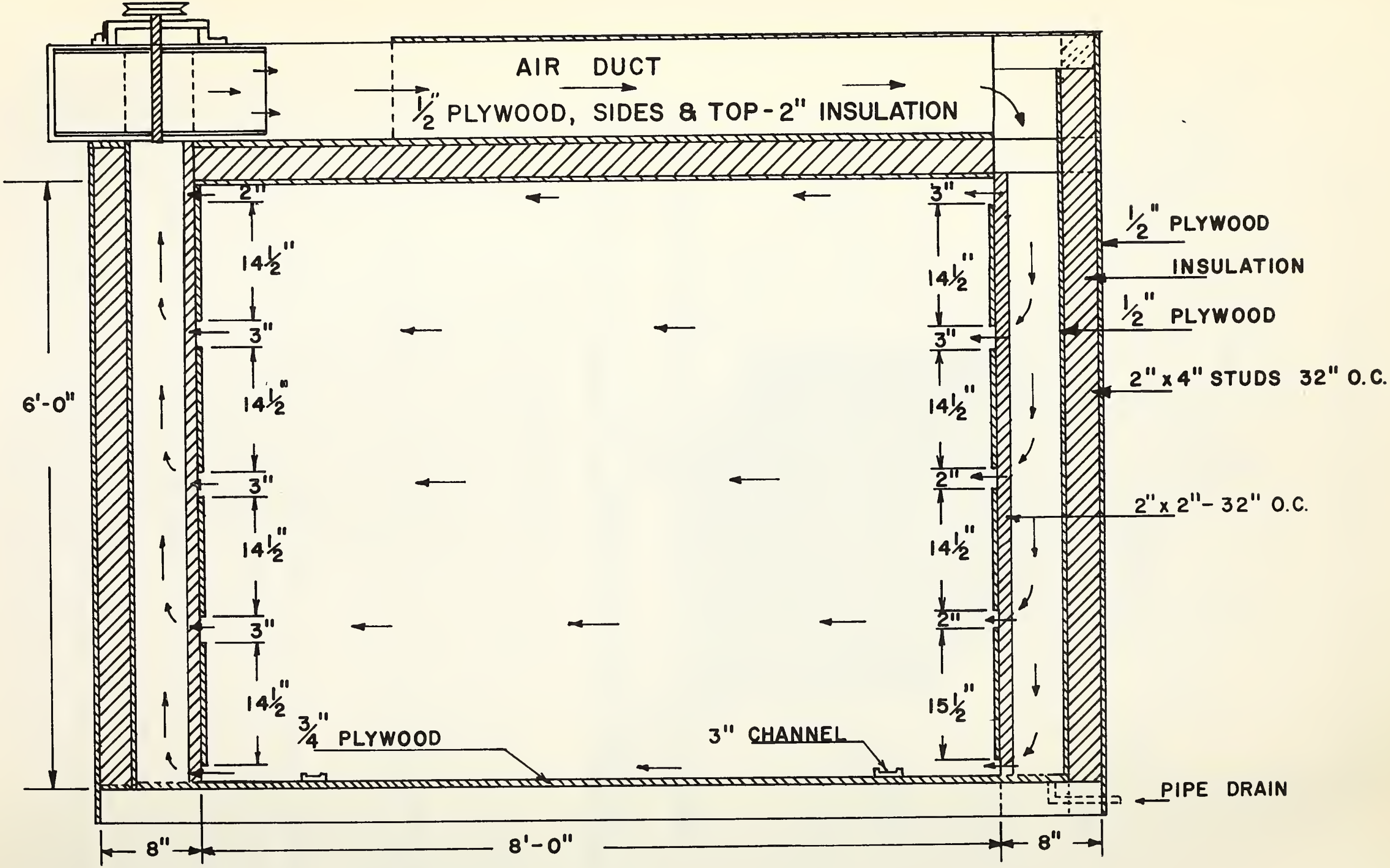

Figure 4.—A cross-section of an aerated steam treatment chamber showing the construction details

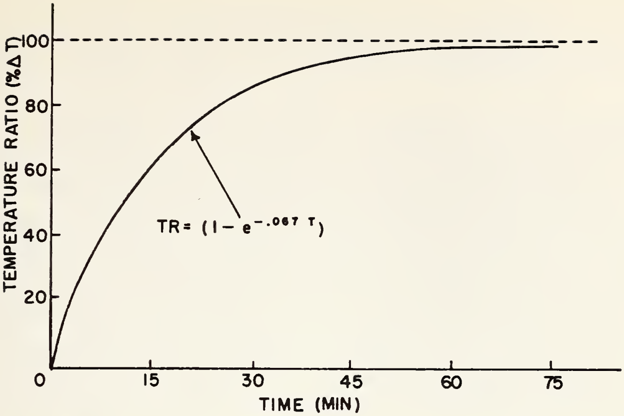

Figure 5.—Relationship between time and percent of the temperature differential, initial temperature minus treatment temperature, acquired during treatment of 15-inch layers of sugarcane seed pieces with aerated steam

Using a general law for heating and cooling, the following temperature ratio was computed:

$$TR = \frac{T - T_i}{T_t - T_i}$$

Where: TR = temperature ratio
T_i = starting temperature
T_t = treatment temperature
T = temperature at any time

When the temperature ratio is plotted against time, the curve takes the form:

$$TR = 1 - e^{\frac{-t}{\tau}}$$

Where: TR = temperature ratio
t = time minutes
τ = time constant, minutes

One time constant, τ, is defined as the time required for the temperature to reach 63.2 percent of $(T_t - T_i)$.

The relationship of the temperature ratio expressed as percent of ΔT and the time of exposure of sugarcane to aerated steam is shown in Figure 5. By applying aerated steam to a treatment chamber loaded with cane in 15-inch layers at ambient temperature, the time constant, τ, was found to be 15 minutes. When the time the system has been operating is known, the TR or percent of ΔT can be calculated. For example, if the system has been operating for 60 minutes, substituting for t and τ in the equation above, the percent of ΔT achieved is found to be 98.2. The starting temperature has a pronounced effect on the time it takes for the cane to reach equilibrium temperature.

Steam generators are sometimes rated in terms of gallons of water converted to steam per unit of time. Heat losses in the delivery system are significant, and results using aerated steam indicate a steam generator rated at 100 gallons per hour is needed to treat a 1 ton load. By staggering the starting times, a 100 gallons per hour steam generator is capable of providing steam for two 1 ton units. The automation of the steam generator is necessary to discontinue steam generation when the amount generated exceeds the requirements of the system. A high-low pressure cutoff switch is provided to turn the steam generator on and off to maintain a steam pressure from 20 to 40 psig (pounds per square inch — gauge). The steam output is piped to the accumulator and a steam trap purges the accumulator of excess condensate. The accumulator is insulated and protected with a relief valve set at 75 psig. Steam is drawn off the top of the accumulator and piped to the flow control valve for use on demand by the treatment chamber.

The flow control valve is normally closed and pilot operated. A bulb installed in the inlet plenum monitors the temperature and actuates the pilot valve, which in turn operates the main valve. The steam is injected into the air duct through a sparger tube. The outlets of the tube should be pointed in an upwind direction for best mixing of the steam and air. A second steam trap is positioned in the system to protect the modulating valve from condensate.

Conclusions

Results using the aerated steam system for heat treating sugarcane to control ratoon stunting disease show several advantages.

1. A relatively short time is required for the system and cane to achieve temperature equilibrium.
2. It provides an environment for efficient heat transfer into sugarcane seed pieces.
3. It has a fast and easy method to vary the rate of temperature change within the treatment chamber.
4. Temperature distribution is uniform within the treatment chamber.
5. It eliminates the accumulation of trash, mud, and extraneous material in the treatment chamber.
6. It eliminates stagnant or polluted water.
7. Sugarcane can be heat treated with trash and leaves attached.
8. It is adaptable for treating and handling cane in bulk.
9. It does not adversely affect germination at the temperature-time combination needed to control ratoon stunting disease under Louisiana conditions.

Equipment Specifications

The following equipment arranged according to Figure 2 is suggested for a complete aerated steam system.

Item 1. *Steam source* — Steam may be supplied to the system by a quality automotive-type steam cleaner, or a steam generator. The steam capacity of the steam cleaner should be 100 gallons per hour per ton of cane treated. Generators should be selected on the basis of 5 hp of steam per ton of cane. The steam generating system should have the following specifications or the equivalent: a pump output of 100 gph (gallons per hour), non-corrosive check valves, and a thermostatic control to protect the cleaner from excessive heat in case of a water supply failure. Water should be available at a rate of 2 gallons per minute free flow with a maximum inlet pressure of 60 psi. The purchaser will specify to the retailer the type of fuel and drive desired with the unit. The unit may be oilfired with an electric motor drive. A standard 115 volt, 60 cycle, 15 amp fused electrical circuit is needed.

Item 2. *Accumulation tank* — The accumulation tank serves as a cushion for the steam from the generator, collects condensate, and provides a steam supply for the system when the steam generator is shut-off by the pressure control switch. For long time use, the tank should be fabricated from a non-corrosive material such as stainless steel or copper with a working pressure of 75 psi and a factor of safety of 4.

If the tank is constructed from more readily available material such as low carbon steel plate, a minimum working pressure of 150 psi is suggested. The conventional propane or ammonia tank has a working pressure of 250 psi and can be used.

The tank should bear a name plate indicating it is constructed according to Section VIII of the unfired pressure vessel code, ASME. It should be fitted with legs at least 12 inches high and have three openings in the vapor zone and one opening at the bottom. A 2-inch layer of insulation should be used to minimize heat loss and condensation.

The size of the accumulator is not critical. However, a 50-gallon tank is suggested. Install the tank with the long axis in a vertical plane to facilitate separating the condensate from the steam.

Item 3. *Steam trap* — Condensate from the accumulation tank can be removed through the ¾ inch Sarco 9-125 (1-125 psi) or an equivalent steam trap without losing pressure in the system.

Item 4. *Pressure gauge* — A pressure gauge positioned on the accumulation tank will let the operator visually observe the pressure within the system. The gauge should be a Duragauge with a 0-100 psig range dial face or the equivalent.

Item 5. *Pressure relief valve* — Protect the tank with a relief valve set to discharge at not over the working pressure of the accumulator. The relief valve must be set at least 20 psi above the steam pressure in the accumulator. A ¾ M x ¾ F relief valve with a 0.750 inch seat diameter will discharge 750 pounds of steam per hour when set at 75 psi. This will protect the accumulator. A Kunkle Valve Company relief valve type 383 or the equivalent is suggested. Pipe the outlet away to a safe discharge area.

Item 6. *Pressure cutoff switch* — At the beginning of the treatment cycle the system will require the maximum output of 100 gph of steam per ton of cane. As the system approaches the treatment temperature of 53°C (127.4°F), less steam is needed. After the system reaches the treatment temperature, the pressure in the accumulation tank will increase. A pressure cut off switch is attached to the accumulation tank to cut off the steam generator and let the accumulator provide steam to the system until the pressure drops to 25 psig. At 25 psig the pressure switch will close and start the steam generator in order to maintain 25 to 40 psig operating pressure in the accumulator. A Square D, Pumptrol, KD, Class 9013, FSG 2, on 20 — off 40, or the equivalent, is suggested.

Item 7. *Steam line strainer* — The strainer should be a 1-inch Spence full flo Al SCY strainer or the equivalent.

Item 8. *Recording thermograph* — A recording of the temperature inside the treatment chamber will provide a record of how the system operated. The operator must know if some component did not function properly. The recorder should be a 110 volt 60 HZ Foxboro model 12R temperature recorder with box pens and a 12-hour rotation chart drive. The recorder is to have a type TA-1B thermal element with a 5 foot flexible bronze bulb union with a bendable bulb type 1542 extension. The recorder should be supplied with Foxboro chart #897427 and an operating instruction manual. A recorder equivalent to the above specifications may be used.

Item 9. *Steam flow control valve* — The steam flow control valve monitors the temperature and regulates the amount of steam necessary to maintain a treatment temperature of 53°C (127.4°F). The valve should be a Spence model ET14 1 inch steam regulating valve, or the equivalent, with a temperature sensing element, 20 feet of flexible tubing capable of controlling the temperature in the system ± 1°C, an adjustment indicator scale, and a dial thermometer indicating 20° — 80°C.

Item 10. *Globe valves* — The system should have 1 inch globe valves installed as shown in the piping arrangement, Figure 1.

Item 11. *Steam injection nozzle* — The nozzle is constructed for the converted hot air boxes using ¾ x 18 inch galvanized pipe with 1/16 inch holes spaced 1 inch apart and installed in the air duct approximately 24 inches downstream from the fan outlet.

Operating Instructions

Preparation of Cane

1. Seed cane may be cut by machine or by hand. The topper should be lowered to mature cane to minimize green trash. The cane does not need to be de-trashed before heat treating.
2. Cane may be loaded for transporting to the treating area with hydraulic grab loaders. The trays or racks used with the treating chamber should be loaded in 15-inch layers.
3. Time between cutting and treatment should not exceed 5 days — 3 days after cutting is suggested. There are indications that treating immediately after cutting may not be desirable. Plant the treated cane as soon after treatment as possible.
4. Load the trays or racks as uniformly as possible. Avoid compaction. Leave approximately 3 inches between each layer. This space will increase as treatment progresses due to the cane settling within the layers.
5. Trays or racks may be unloaded for transporting to the field with hydraulic grab loaders, chain slings, or fork lifts. Mechanical loaders and trailers used to handle untreated cane should be isolated from the treatment operations to prevent reinfection of treated cane.

Operation of the Aerated Steam System

The procedure for operating the system follows. Sugarcane should be treated with a air-steam mixture for a total treatment period of 4 hours at 53°C (127.4°F).

1. Open the water supply to the steam generator.
2. Turn the steam generator pumping unit on. Make sure water is flowing through the steam cleaner then turn the burner on. As the unit begins to generate steam, re-check the water to the steam generator. The generator will burn up very quickly if there is no water in the system. An automatic water level cutoff valve should be provided with the steam generator.
3. Allow the steam pressure in the accumulator to build up until the cutoff pressure switch stops the steam generator (40-50 psi). Check to see that the steam trap attached to the accumulator is functioning (intermittently discharging water.)
4. While the steam pressure is building up, check the steam flow control valve indicator setting. Rotate the hand wheel until the pointer points to the number that corresponds to 53°C (127.4°F) on the dial thermometer.
5. Move the rack or trays loaded with seed cane into the treating chamber. Close the door.
6. When the pressure in the accumulator reaches the cutoff pressure (approximately 40 psi) and assuming the cane is in the chamber, turn the

circulation fan on and open the steam control valve to allow steam to flow into the treatment chamber. Three globe valves shown in Figure 1 control the flow of steam to the treating chamber. Valve 1 should be open all the time. Valve 3 is normally closed. Valve 2 starts and stops the flow of steam to the treatment chamber. Leaving valve 1 open keeps the regulating valve hot and ready to use at all times. Close 1 and 2 and use 3 if control valve malfunctions.

7. Turn the temperature recording thermometer on. Record the starting time and date on the chart.

8. A mercury thermometer should be inserted at eye level into the aerated steam entrance plenum. Observe the temperature of the mercury thermometer and the control valve. Rotate the hand wheel on the control valve to adjust the temperature in the treatment chamber to 53°C (127.4°F) as indicated by the mercury thermometer. If the temperature of the mercury thermometer does not agree with the temperature gauge on the control valve, adjust the gauge to indicate the same temperature as the thermometer. When adjusting the chamber temperature, rotate the hand wheel clockwise to increase the chamber temperature and counter clockwise to decrease it. As a rule of thumb, a rotation of approximately 1 inch will change the temperature 1°C.

9. Expect the temperature in the cane to reach 53°C within an hour (assuming the starting temperature is at least 24°C).

10. In case of a steam control valve malfunction, close the two globe valves, 1 and 2 in Figure 1, that isolate the control valve from the steam supply line. Control the chamber temperature by hand. Using the by-pass valve (3), carefully meter the steam to the air duct to keep the temperature at 53°C. Get competent help to service the control valve.

11. After 4 hours, shut off the supply of steam to the treatment chamber (close valve 2), turn the circulating fan off, and open the door.

12. Mark the temperature chart to indicate when the treatment was completed. Indicate on the chart where the cane is to be planted and file the chart for future reference.

13. Unload the treatment chamber. Do not leave the cane in the closed oven after the 4 hours. Germination will be seriously affected.

Some Problems to Anticipate

1. When using hard water, expect erratic valve operation. Minerals in the water will build up in the steam generator coils and also tend to block the control valve passages. *Use soft water.*

2. When treating two chambers with only one steam generator, be sure to stagger the starting time 2 hours. This allows the first chamber to settle to a good equilibrium temperature before the second chamber demands steam.

3. The control valve will not function satisfactorily when water logged

or when trash or rust is in the water.

a. When starting a cold box, make certain the steam trap at the accumulator is purging all water from the system. The steam trap at the control valve must purge any condensate from the line before getting to the control valve. If the temperature cycles up and down without reaching equilibrium, the control valve may be waterlogged.
b. If the box fails to come up to temperature, suspect trash in the valve. Clean all screens. Check the orifice to the pilot valve and the orifice in the line below the main valve diaphram. A strainer should protect the control valve in addition to the fine screen in the body of the pilot valve.
c. If the accumulator fails to come up to the 40 psig cutoff pressure, the steam generator is not functioning properly. This may be due to several routine problems. If the generator burner is not operating properly, check with the supplier.

SELECTED REFERENCES

Anonymous. "Ratoon Stunting Disease — Heat Treatment and Germination." South African Sugar Association Experiment Station Annual Report, 1967-68.

Edison, S. and K. Ramakrishnan. "Aerated Steam Therapy for the Control of Grassy Shoot Disease (GSD) of Sugar Cane." The Mysore Journal of Agricultural Science, Volume II, No. 4, 1972.

Baker, K. F. "Aerated Steam Treatment of Seed for Disease Control." Horticultural Research, 9: 59-73.

Cochran, B. J. "Development of an Aerated Steam System for the Control of Ratoon Stunting Disease in Sugar Cane." ASSCT Proceedings, Volume 5, 1976.

Egan, B. T. "Heat Treated Cane and Healthy Cane Aren't Necessarily the Same." Cane Growers Quarterly Bulletin, Queensland. Volume 21, No. 4, 1958.

Forbes, I. L. "Ratoon Stunting Disease of Sugarcane." Louisiana Agricultural Experiment Station Bulletin, No. 532, May, 1960.

King, Norman J. "The Ratoon Stunting Disease Problem." Cane Growers Quarterly Bulletin, Queensland. Volume 17, No. 1, 1953.

Knust, G. H. "Notes on the Heat Treatment of Cane Plants at the Bundaberg Sugar Experiment Station." Cane Growers Quarterly Bulletin, Queensland. Volume 17, No. 1, 1953.

Mungomery, R. W. "Obstacles to be Avoided in Hot Water Treating Cane Setts Against Ratoon Stunting Disease." Cane Growers Quarterly Bulletin, Queensland. Volume 17, No. 4, 1953.

Pollock, J. R. "Hot Water Treatment Against Ratoon Stunting Disease." Cane Growers Quarterly Bulletin. Volume 17, No. 1, 1953.

Thompson, G. M. "The Diseases of Sugar Cane in Natal Ratoon Stunting Disease." Experiment Station of the South African Sugar Association Bulletin, Natal. No. 9, November, 1958.

August 1978

Bulletin No. 710

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A Study of Owners of Small Timber Tracts in Louisiana

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Acknowledgments

The author extends his sincere appreciation to each person and agency that contributed to this study. Special thanks are extended to each landowner interviewed for answering the questions, many of which were both probing and personal. Appreciation is expressed to personnel of the Louisiana Forestry Commission for assistance in completing part of the interviews in two of the survey areas, and to Dr. Barton A. Farthing, Department of Experimental Statistics, for aid in the experimental design, statistical analysis, and interpretation of the results. Thanks are also extended to Professors Thomas Hansbrough, Paul Y. Burns, A. B. Crow, and Robert W. McDermid of the School of Forestry and Wildlife Management, Extension Forester Alden C. Main, and State Forester Donald L. McFatter for reviewing the manuscript.

This study was supported in part by funds received under the McIntire-Stennis Cooperative Research Program.

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A Study of Owners of Small Timber Tracts in Louisiana

CLIFTON B. MARLIN*

Introduction

The Southern Forest Resources Analysis Committee in 1969 published *The South's Third Forest,* which outlines the requirements for timberland development and production necessary to provide the multiple-use benefits that come from productive forests. These requirements include producing 2.3 times as much wood by the year 2000 as was harvested in 1968, and this accelerated production must be accomplished on a decreasing forest land area. If production is to be increased by this amount in Louisiana, it will require the adoption and application of advanced forest management practices by all forest landowners, and especially by the owners of small tracts of timber.

There are 93,732 private forest landowners in Louisiana who each own less than 80 acres of forest land, and 18,538 with ownerships varying in size from 80 to 499 acres (Gunter, 1975). These 112,270 owners control 40 percent, or 5.3 million acres, of Louisiana's forest land and represent 98 percent of the state's forest landowners. An additional 2,423 nonindustrial owners with holdings between 500 and 4,999 acres in size (average: 1,181 acres) own more than 2.8 million acres.

The Louisiana Legislature in 1970 passed House Concurrent Resolution No. 101 declaring that it shall be the public policy of the state to cooperate and lend assistance in developing the forests of Louisiana. The resolution requested that all resource management agencies of the state cooperate, accelerate, and intensify their related resource development programs. Educational agencies were requested to accelerate their research and extension programs and the teaching of resource values, needs, and individual citizen responsibilities for these multiple-use resources. All woodland owners were encouraged to manage the forest land resources they have available to meet the goals for Louisiana's multiple-use Third Forest of the year 2000. The federal government and its agencies were asked to intensify their efforts to meet their responsibilities and fulfill authorized programs with particular reference to protection and small landowner assistance. Also, the Louisiana Forestry Association is committed to the development of the Third Forest.

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Louisiana is blessed with a long growing season (250 to 270 days per year), adequate rainfall (50 to 60 inches), mild temperature, and many desirable species of trees. The productive capacity of the forest land area in Louisiana is as good as that of any state and better than that of most states.

Many benefits are derived from forests. It is, therefore, important that forests and associated resources be perpetuated so they may continue to serve as an important part of the present and future environment and economy of Louisiana and the United States. The interest of the human population in forest production is in direct proportion to the benefits received from forests. The recipients of benefits should also be interested in a basic forest management program in proportion to those benefits.

Benefits derived from productive forests include wood, water, recreation, wildlife, forage, aesthetics, and soil stabilization. Some of these are tangible and can be expressed in monetary terms. Others, such as aesthetics, water, soil stabilization, and many forms of recreation and wildlife, are intangible and cannot be expressed in terms of money with the present state of knowledge. However, they are very important and the perpetuation of them must be emphasized.

Forests provide the raw materials for one of the most important industrial structures in Louisiana. The Louisiana Forestry Commission reported 316 primary wood-using industries in Louisiana in 1976 (Martel and Burns). The plants are well distributed throughout the state (Figure 1). The wood industry in 1976 paid approximately $129 million to landowners for stumpage, provided employment for more than 32,000 industrial workers (making it the leading industrial employer in Louisiana), and had an annual payroll of about $370 million.

A report of the U.S. Forest Service showed the total value of wood products in Louisiana was 22.1 times the stumpage value in 1958 (Hair, 1963). A study in Louisiana (Marlin, 1968) found that the average total value of wood products in the state was 27 times greater than the stumpage value for the 14-year period from 1947 through 1960.

Also, most of the intangible benefits associated with forests, such as water, wildlife, recreation, aesthetics, clean air, sound barriers, and soil stabilization, go to the general public.

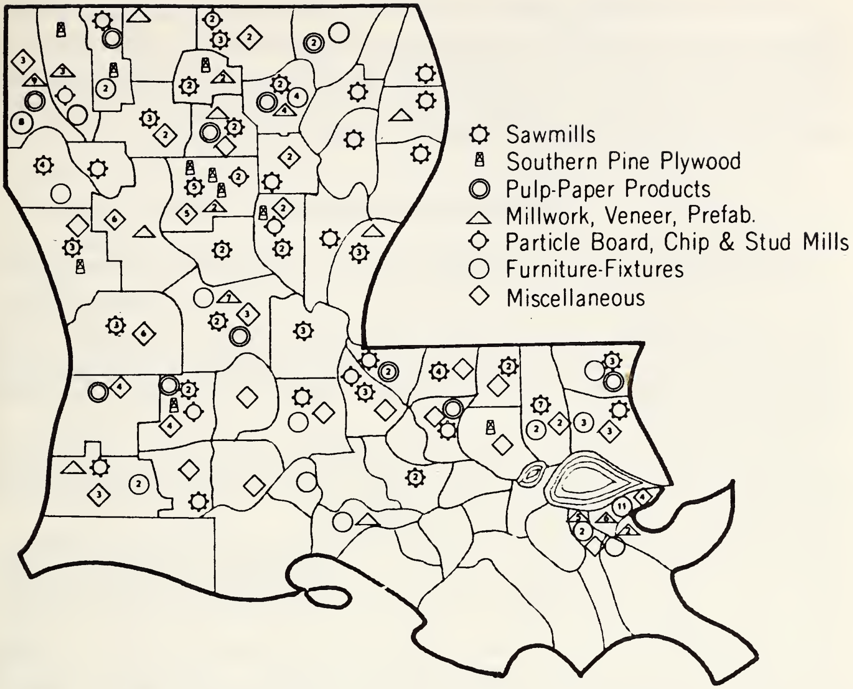

Figure 1.—Location of wood-using industries in Louisiana, 1971. (Source: Louisiana Forestry Commission.)

Objectives

Adequate facts concerning owners of small tracts of forest are essential as a basis for developing programs to improve the status of management on such holdings. The purpose of this study was to secure facts that will be helpful in guiding action programs.

The main objectives were:

1. To review data and previous research that have attempted to characterize, measure, analyze, and describe the various attributes of owners of small tracts of forest land.
2. To look at the economic, institutional, and other factors relating to small forest ownerships.
3. To study characteristics of landowners and seek relationships between owners, their land, and their forest management practices.
4. To determine from past experience and the current study what steps may have the best chance of leading to increased production.

This was a fact-finding study to seek information that would be helpful in making recommendations for programs to increase the productivity of forests on small ownerships. It was the first state-wide study in Louisiana of owners of small tracts of forest land. Field interviews were completed during the period of July 1971 through July 1974.

Review of Literature

Throughout the years of scientific forest management in America, the private nonindustrial woodland owner has done little to improve production on his holdings. Since owners of small timber tracts are so numerous, own so much land, and practice little management, a detailed review of the literature was made in an effort to identify characteristics associated with forest management.

Several studies have been made in an attempt to learn more about small landowners. Most of these inquiries were based in the South and East where private landowners are most numerous.

Some studies were made in parts of Louisiana. Folweiler (1944), McDermid, et al. (1959), and South, et al. (1965) dealt with land ownership and management practices in some parishes. Jones and McKean (1962) compared innovator and noninnovator owners. In the southern United States, Martin, et al. (1960) characterized the nonmanagers of small woodlands in Alabama. Anderson (1968) polled North Carolina landowners to discover factors influencing forestry practices. Yoho and Muench (1962), Webster and Stoltenberg (1959), and Somberg (1969) were others who wrote on forest owners' characteristics. The studies did not contain the same variables, but these authors and others provided much background information on topics considered in this study.

McArdle (1956) observed that the findings of the nationwide *Timber Resource Review* showed that: "The real key to America's future timber supply lies in the hands of one out of every 10 families who own small forests.[1] Most of the lands owned by forest industries and public agencies are left in reasonably good growing condition after cutting, but on over one-half of the recently cut farm and other small private forests conditions for future growth are far from good."

Stoddard (1961) said:

> The objectives of forest owners depend in large part on how and why they obtained their land. In the case of farmers, these questions are largely answered by the fact that the woodland has been a part of the farm unit since the original settlement, a part usually located on steep, swampy, or rocky land unsuitable for crop production and used

---

[1] The U.S. Forest Service classifies ownerships of less than 5,000 acres as small.

> primarily as a source of firewood and building materials.
>
> Forest land in the hands of nonresident nonfarm owners usually consists of a small tract in a heavily wooded area where a larger block of land has been cut of its best timber and divided up. Few of the ownership studies cited develop the methods of acquisition in any detail, but they do show that a major portion of the land was purchased rather than inherited. The principal reasons for purchase given by owners were: investment, resale at a profit, reforestation and future returns, a variety of recreational uses and speculation in mineral potentials. . .
>
> . . .One very important aspect of forest ownership which previous studies have never been able to develop satisfactorily is that land ownership seems to satisfy a basic psychic urge quite apart from economic motives. This subconscious drive is seldom brought to the surface by interviewing and questionnaire techniques, though it does develop in personal discussions. When people derive little or no income from land and continue tax and other payments to hold it, it is unlikely that the primary incentive is an economic one except where land is held for speculation or mineral development.

Occupation was a popular characteristic considered. In accord with several studies, James, Hoffman, and Payne (1951) found that the majority of owners they observed were farmers. Yoho and Muench (1962) emphasized that 75 percent of all small, private ownerships are concentrated in farm units but only half of the owners list themselves as farmers by occupation. Coutu (1961) suggested that improved employment opportunities off the farm had resulted in an increase in part-time farming which was compatible with forest management. South, et al. (1955) cited farmers as having adopted more forest practices than nonfarmers, and Ramke (1960) found that bankers, industrialists, and farmers did a better job of timber management than owners with other occupations. However, Pleasonton and Guttenberg (1961) said farmers in northern Mississippi who owned small forests were less likely to adopt forestry than were the nonfarm woodland owners. While the results varied among studies, one definite trend was that the number of full-time conventional farmers (row crop and livestock) was decreasing.

The findings of investigators in regard to age of owners as a factor in forest management have varied. LeVasseur (1963) and Hestbeck (1963) found more innovators of forestry below 60 years of age than above 60. McDermid, et al. (1959) found no correlation between age and forest practices in a St. Helena Parish, Louisiana, study. Ramke (1960) stated that owners above 40 were better managers. Perry and Guttenberg (1959) found younger owners were more willing than older owners to seek professional help. However, most studies found that older people own the majority of the forest land, but that most of them feel their remaining life span is insufficient for them to realize much profit from a forestry venture.

Investigators have also looked into the size of ownership as an influential factor regarding forest practices. Gunter (1975) found the number of people owning more than 500 acres of forest land was decreasing. McDermid, et al. (1959) found that larger owners adopted forest practices more frequently than did smaller owners. This finding was supported by McClay (1961), Barrett (1962), and South, et al. (1965). Sizemore (1970) said owners of very small holdings tend to value each tree instead of visualizing or evaluating the stand of trees.

While most investigators agreed that size of ownership was a significant factor concerning small forest owners, varying conclusions were drawn about the role of education. Chamberlain, et al. (1945) indicated that the average nonindustrial landowner lacks an understanding of forest management and needs a program of demonstration as well as education. Lack of technical knowledge was a major reason cited by landowners in Vernon Parish, La., for their insufficient forest management (Stevens, 1963). McDermid, et al. (1959) found that owners who had some college education practiced forest management at a significantly higher level than owners with only a grammar school education. Yoho (1961) also found education to be a significant factor in the acceptance and practice of forestry. He mentioned that owners with at least 10 or 11 years of formal education were more favorable toward forestry than those with less education. South, et al. (1965) revealed that most owners who adopted forestry were educated beyond high school.

Bradford and Marlin (1972) found that a high level of understanding of basic forestry concepts was strongly associated with a high level of adoption of forest practices by owners of small tracts in two Louisiana parishes. However, there was a time-lag before acquired knowledge resulted in the adoption of improved practices on the ground. Owners in their 50's scored highest in knowledge of forestry concepts while owners more than 60 years old scored highest in adoption of forest practices.

Findings in regard to the importance of the location of an owner's home in relation to the location of his tract of timber have varied. LeVasseur (1963) observed more innovators living on their woodland than away from their woodland. Conversely, Hestbeck (1963) found that innovators were less likely to live on their holdings than were noninnovators. Ramke (1960) maintained that absentee owners could be successful in their forest operations if they had responsible managers. Coutu (1960) reported that a favorable condition for forestry existed with rural, nonfarm resident owners. He added that one of the optimistic forces of forestry was an increase in this type of small, private landowner.

Although Barrett (1962) and Craig (1972) both cited forest credit as an incentive to practice forestry, most researchers have found scant interest among owners for loans. A low percentage of owners in an Arkansas study by Perry and Guttenberg (1959) desired a loan to finance a forest management practice. Anderson (1968) said most of his interviewees utilized no outside funds or labor for forest practices but relied on their own resources. Forest credit was observed by James, et al. (1951), Southland and Tubbs (1959), and McClay (1961) to be of little interest to respondents in their studies.

Various conclusions were drawn from the research on tenure of the small, private landowners. McDermid, et al. (1959) and Pleasonton and Guttenberg (1961) associated good forest productivity with tenure of more than 10 years. On the other hand, Seigworth (1956) and Ramke (1960) cited two decades as the length of tenure favorable to sound forest management. In general, past studies indicate that an increase in the years of ownership enhance the practice of forestry by private landowners.

The leasing of small, private ownerships to those in a position to apply intensive management practice could increase productivity. Coutu (1960) suggested that leasing could prove to be an excellent method of utilizing idle woodlands, and Smith (1972) listed leasing as an incentive to propagate trees on small, private ownerships. However, McClay (1961) found only a small percentage of owners were interested in the idea of leasing their holdings. Likewise, Sutherland and Tubbs (1959) reported that approximately one-tenth of their interviewees expressed a desire to lease their woodland, while Somberg (1971) found that 20 percent of the owners of nonindustrial forests in Alabama were interested in entering a lease of 25 years or more.

Mignery (1956) and Perry and Guttenberg (1959) found a relationship between income or assets and the practice of forest management, with management generally increasing with assets. Yoho (1961) found that total income played an important role in adoption or nonadoption of forest practices. South, et al. (1965) said forests were not the major source of income for owners. However, most authors concluded that more intensive management was accompanied by higher owner income and assets.

An attempt to determine how landowners used and managed their forest lands was made in some studies. The majority listed timber growing as the main use (Sutherland and Tubbs, 1959; Perry and Guttenberg, 1959; McClay, 1961; Jones and McKean, 1962; Toms and Marlin, 1972, and Fontenot and Marlin, 1974). James, et al. (1951) found 41 percent of the owners did nothing to stop fires, and more than half of the owners either had no concept or a misleading concept of the definition of timber management.

Sutherland and Tubbs (1959) found 75 percent of the owners applied no forest management practices, and the remaining 25 percent gave planting as the most popular practice. Respondents listed either lack of area or lack of time as the reason for not planting. Tree planting was also found by Perry and Guttenberg (1959), McClay (1961), and Anderson (1968) to be the most popular practice. McDermid, et al. (1959) listed 24 percent of the respondents as being involved in some kind of management. McClay (1961) said only one-third of the owners applied forestry practices. Anderson (1968) found that many owners engaged in forest management had adopted practices in only two or three categories. In general, actual participation in forest management was low, with planting of trees being the most common practice.

Harvesting, including timber sales, was another practice discussed in some studies. Only 24 percent of the owners of small tracts had sold timber in central Wisconsin (Sutherland and Tubbs, 1959). A written contract was used in 35 percent of the sales, and 23 percent of the sales were by lump sum. Perry and Guttenberg (1959) found that 27 percent of the interviewees had sold timber in the past decade, and payment was mostly by scale at the woodyard. James, et al. (1951) found that only 28 percent of the owners rated ''fair'' or above in quality of timber cutting practices. Pleasonton and Guttenberg (1961) found that only 4 percent had used timber marking in their sales. Chamberlain, et al. (1945) believed that inadequate harvesting contracts were responsible for poor cutting practices on nonindustrial tracts. In a citation of a case history of profitable forest management on small ownerships, Bethune and LaGrande (1960) listed timber stand improvement as a necessary ingredient of a good forest management plan. In observing the problems of the small-forest owner, Barrett (1962) emphasized planting, timber stand improvement, and harvesting as areas of forestry that need to be increased and/or improved.

With regard to harvesting, Anderson (1968) disclosed that the majority of respondents did not know the value of timber harvested and relied on a buyer's estimate. In general, past studies seem to point to a lack of understanding of the economic and management benefits of good harvesting and selling techniques.

Toms and Marlin (1972) found that, although forest production was low in comparison with that on well-managed land, the owners of small tracts of timber in northwest Louisiana used better methods of harvesting and selling timber, applied more timber stand improvement, and had more interest in forest credit and in leasing of their lands than respondents of earlier studies in Louisiana, the South, and the U.S.

Fontenot and Marlin (1974) found timber growing to be the main use of forest land by 64 percent of the owners of small tracts of timber in southwest Louisiana. Grazing was the primary use listed by 28 percent of the owners, and it was the most popular secondary use. The young owners listed grazing as the number one use of forest land more frequently than other age groups. Sixty-eight percent of the interviewees grazed cattle on their forest land.

A study of woodland management practices among owners of small tracts in 17 Louisiana parishes was made by Jones and McKean (1962). Woodland owners interviewed were asked to rank, in order of importance, 12 listed reasons why owners do not use better management practices. The leading four reasons were:

1. It takes such a long time to grow a crop and get income.
2. Insufficient technical knowledge.
3. Cost of practices outweighs possible benefits.
4. More rewarding activities on which to use their time and money.

In the same study, woodland owners were asked to complete the sentence, "The thing I *like* most about my woodland is ______." The most frequent comments and the number of owners making them were:

Liked most	Number of owners	Percent
Economic returns	267	62.4
Beauty, like to watch it grow	30	7.0
Wildlife, recreation, hunting	27	6.3
Pride of ownership	12	2.8
Very little expense and care to maintain	11	2.6
Timber	11	2.6
Protects cattle from weather	9	2.0
All other	61	14.3
	428	100.0

Interviewees were also asked to complete the sentence, "The thing I *dislike* most about my woodland is ______." A majority of the owners felt the question did not apply to them since they did not dislike their woodlands. These owners did not respond to the question. Reasons given by those responding were:

Disliked most	Number of owners
Returns too small	57
Growth too slow	32
Problems of underbrush	30
Need it for pasture land	17
Holdings too small	14
Grown up in undesirable species	13
	163

Answers to the above two questions point to the fact that economic returns were the main reason for growing timber, but the income was slow in coming and low in rate of return. This is because it takes a long time to grow a tree and only one of the many goods and services derived from forests has a good market. This is wood fiber, and the grower gets only about 4 percent of its total value.

A number of studies have shown that forest management yields a low rate of return to the landowner. A report by Resources for the Future, Inc. (1958) contained useful data and an analysis of costs and returns from forestry, as follows:

> Until recently there have been few records of continuously managed forests which would reveal relationships between net income and capital investment as a measure of profitability. To be meaningful, the accumulation of such figures requires complex and specialized record keeping over a considerable time. Probably the best of the available data are to be found in the records of the so-called 'Farm Forestry Forties,' located in the various experimental forests of the U.S. Forest Service. Other estimates have been made from growth and yield data pertaining to larger areas.
>
> Rapid growth rates in the southern pine region, which are a result of heavy rainfall and a long growing season, have caused that area to be regarded as the most profitable producer of forest products in the country. Close behind are the Douglas-fir and redwood forests of the moist Pacific Northwest, and the northern pine forests which also are good wood producers. The hardwood types are generally slower in rate of growth. . . .

The report showed that net percentage return on the appraised value of the timber stands before income taxes for three experimental forests in the East were 7.5, 3.6 and 2.4 for southern pine, red and white pine, and northern hardwoods, respectively.

> The data given above tend to confirm the assumed advantage of the southern pine forests. However, this is offset in part by heavier annual costs. While these net returns are comparable with those on some of the more conservative bond issues, they must be regarded as minimal returns on invested capital.

Stoddard (1961) wrote:

> Although we have no way of knowing how the several ownership motives may be apportioned nationally, it appears that many are willing to pay the holding costs of small tracts of wild forest land and some are willing to invest in tree planting but relatively few own their lands in order to carry on an active forest management program

> designed to provide regular crops of forest products. Although ownership may be in fairly stable hands, there seems to be insufficient economic motivation in forestry to induce the owner to grow and produce forest products on a systematic basis, compared with returns from other activities in which he can or does engage. Where high yields of valuable species are possible on better growing sites (as in the Southern pine region), considerably more incentive exists.
>
> . . . The heart of the problem appears to lie in the small scale on which businesslike forest management must be practiced on these little woodlands. The costs to the owner simply outweigh any prospective returns—except where liquidation once in a rotation is the practice.

In a study by Marlin (1968), the value of manufactured products derived from Louisiana forests during a 14-year period, 1947-60, was $7,789,200,000. The forest landowner, who grew the raw material, received less than 4 percent while others received more than 96 percent of the total value of the wood products. In other words, every time the forest landowner received $1 for stumpage, other people and governments (federal, state, local) received $26.79 for felling, limbing, bucking, skidding, loading, hauling, manufacturing, drying, selling, shipping, and using that dollar's worth of stumpage. Therefore, timber is a more important economic and consumer product for the "general public" than it is for the owner.

Hair (1963), in a study titled *The Economic Importance of Timber in the United States*, determined that in 1958, the study year, timber increased in value almost 25 times between the stump and delivery of the finished products. In that year, the gross national product originating in timber-based activities was $24.75 billion. As shown in the following tabulation, only 4 percent of the total value of finished wood products was returned to the owner for growing the timber. In that year, about one person of every 20 employed in the U.S. was engaged in some kind of timber-based economic activity.

	Total income	
Activity	Percent	$ (Billions)
Growing	4	1.0
Harvesting	6	1.50
Primary manufacturing	16	3.85
Secondary manufacturing	22	5.45
Construction	31	7.60
Transportation and marketing	21	5.35
	100	24.75

Montgomery and others (1975) could not economically justify any forest management by landowners on almost half of the 18 million acres of commercial forest in small ownerships in Georgia. Their projection was made on the basis of stumpage prices estimated through the year 2000. Anticipated income to the owners of 8.5 million acres of forest land did not even cover annual ad valorem taxes under the simplest management program.

Furthermore, Tucker (1975) stated: ". . .on large industrial ownerships the after-tax return on the woodlands entity as a self-standing profit center most probably would be no more than 2 to 3 percent. Therefore, industry's justification for owning timberland may be rationalized as:

"1. Supporting the long-term investment in and the profit potential of the manufacturing facility by minimizing its dependency on the outside sources of raw materials.

"2. Reducing the impact of run-away prices of open market wood under demand stress.

"3. Assuring a dependable source of raw material at reasonable cost."

Sizemore (1970) said: ". . . the returns that are afforded by investments to improve woodland productivity are distinctly marginal." He estimated that investments in forest management would produce returns of 3 to 5 percent.

Porterfield (1975) concluded that the reason 2.5 million acres of commercial forest land in Arkansas were converted to other uses from 1959 to 1969 was because it was more profitable for the landowner to have the Delta lands producing annual crops than hardwood timber.

Myers (1973) said:

> . . . the small forest landowner is no problem to himself. He is only a problem to those of us who are seeking to motivate him to do some things we would like for him to do, primarily to get him to invest some of his hard-earned money in growing trees. When he does not respond, he may actually be smarter than we give him credit for being. Dr. Jack Muench of the National Forest Products Association was likely the first one to say that, and I believe it is true. This small landowner usually has only a limited amount of cash and has a low deferability of income. Low deferability of income means he is frequently over committed. He has more commitments than he can meet, more bills than he can pay. Many of us are acquainted with this problem on a first-hand basis.
>
> Moreover, when the small landowner has the money available to invest in development of his timberlands, he would be less than astute if he did not consider his investment alternatives. Remember, we are talking about a hard-nosed business proposition, and keep in mind

further there is absolutely no moral or other reason for the landowner to invest his money in growing trees. Within this climate of consideration, where should he put his money? He should put it where his capital will be protected and his rate of return will be the maximum.

The report, *The South's Third Forest*, indicates the landowner can expect from 5 to 7 percent net return on investment from timber growing activities. Furthermore, the risks of fire, insects and disease, ice storms, etc., are high and markets apt to be uncertain. In addition, the owner can expect to wait at least 10 years before getting his first return on investment. It is true that real estate values may appreciate, but this is to a degree offset by the unknowns of future ad valorem taxes. Moreover, this appreciation of capital would likely occur without expenditures for forest development. So we wind up with a so-called 'Mexican standoff' on real estate appreciation.

Where does this leave the landowner in considering investment alternatives? Well, he can count on a likely 5 to 7 percent return on his investment if his timber doesn't burn up, or the bugs don't get it, and there is an available market. In addition, of course, his money is tied up for 10 years before he gets his first return.

Now let us examine for a moment the other investment alternatives available to the small owner. He can put his money in the local bank and get up to 5 percent, with his capital guaranteed and immediately available. He can also put his money in a savings and loan bank and draw up to 6 percent on 2-year certificates, again with his capital guaranteed.

If the owner can and wants to get into the cattle-raising or rowcrop farming business, these offer other alternatives. These are likewise high-risk ventures, but his payoff comes in a shorter period of time and returns on investment may be 12 percent or more.

Faced with this set of alternatives—to name a few — and a low deferability of income, what would you as a timberland owner do?

McKnight (1973) said:

> . . . we are not going to engender the interest of the nonindustry private owner to really practice forestry on a big scale without an incentive program of some kind. It may come from state, private, or federal sources. It may come from all three.
>
> . . . it has been my reasoning, and the rationale of others, that the capital investment required to increase productivity of forests on nonindustrial ownerships may well be a public concern, at least partially. That initial investment does assure the nation the goods and services produced by forests if the individual landowner assumes his

stewardship in the management of that investment. We should also consider that people other than the owner use that land in many ways. They look at it, walk through it, watch the wildlife, hunt on it, and use the water, wood, and wood fiber produced by it. There are also other amenity benefits. So this is a payment, in effect, for using the land in a certain fashion and to assure its full productivity.

The report of the President's Advisory Panel on Timber and the Environment (1973) said that:

> A major goal of national forest policy must be to achieve, during the period 1990-2020, a relatively high timber harvest from nonindustrial private woodlands. Whether or not this goal will be attained depends largely on measures initiated in the 1970's and 1980's.
>
> The immense area, low stocking, modest growth, and modest rate of harvest of the 'other private' lands makes them the listless giant of forestry. If the growth rate of these woodlands could be increased to match that of the timber industry forests, the effect would be an increase of one-fourth in the average annual growth of all American forests. Part of the problem of getting more output from these lands is technical, part is economic, and part is motivational. Taking into account the present quality and stocking of timber on 'other private' lands, one can only conclude that the current growing stock must be improved to serve as an effective 'factory' to produce timber for projected future demands. The small area in the typical ownership makes many forestry operations unduly costly per acre, or provides only limited incentive to the owner to apply his resources to forest management.

Skok and Gregersen (1975) listed a number of public policy instruments that could be used to intensify forest management on private ownerships. They suggested incentives as the most logical way of increasing the attractiveness of financial returns from forestry by minimizing the private cost impact of investments in forest management.

They also noted that, in recent years, agricultural conservation program payments for forestry practices have been, at a national level, only slightly more than 1 cent per acre of nonindustrial private forest land.

Worrell and Irland (1975) wrote: "Policies to raise the level of private activity in forest management encounter obstacles of low profit, indifference, lack of ability, lack of knowledge, and conflict with other goals." The writers said policies at the economy-wide level were best suited to overcoming the obstacles of low profitability, with the federal government being the most effective agency to develop and implement such policies. The remaining obstacles could be minimized by action by all appropriate governmental and private institutions.

Mills (1975) stated: ''Several major analyses of timber production opportunities indicate that there are millions of acres of profitable investments which small-owner assistance programs can stimulate. The problem of priority assignment is how to find the payoff acres while sidestepping those which are unlikely to contribute to program goals.''

Anderson (1975) said: ''Entice small-forest owners into forestry with a rewarding experience, and they will finance progressively more intensive management in their woodlands. Foresters would agree that applying this theory requires more than efforts to educate owners and give them technical aid. Financial assistance has been tried in the form of cost sharing and rental payments.''

Gould (1975) stated: ''. . . several flaws in the present forestry situation could be solved by actions like those that worked with farmers . . . . forestry does suffer some of the malaise that once afflicted agriculture, and some of the remedial schemes might work again. As in farming, we should aim for that critical mass of public action needed to create a new and improved forest planning climate. ... If we really wish private owners to produce more of such public, nonmarket values than they need for themselves, it seems only fair that the public should make a cost contribution. Practices aimed at these nonproduct values should figure more prominently on new cost-sharing lists.''

McKillop (1975), in an article on social benefits of forestry incentive programs, asserted:

> Reductions in consumer outlays for wood products and dampening of future price rises are the major gains to the nation as a whole, but gains to geographical regions or sectors of the economy from forestry incentive programs may be appreciable. Since timber-growing and wood-processing enterprises are frequently in depressed rural areas, additional economic activity may significantly help achieve employment and income goals. ... The unique character of forest management investments itself might justify the forestry incentives programs. No other type of private investment holds the same degree of uncertainty. No other business is faced with the same combination of fluctuating prices and long investment periods. Industrial forest owners may have the expertise to appreciate that future prices for wood products will be substantially higher than present levels and that intensified timber management is a sound business investment. But the nonindustrial owner does not have this knowledge and confidence. The willingness of government to bear part of the cost may indicate to him the social merits of investment and, in addition, provide a means by which uncertainty may be reduced.

McKillop said a continuing program of intensified management applied only to investment opportunities that would earn a rate of return of at least 5 percent would cover the direct costs including interest charges. Also, secondary benefits from such a program would be substantial when it was fully underway.

Mills and Cain (1976) found the overall performance of the Forestry Incentives Program (FIP) was favorable during the first year of operation in 1974.

Chambers (1976), working on the Third Forest Program in Louisiana, had the following to say about forest needs on nonindustrial lands: "The landowners are not going to accomplish the job themselves. And my experience over the last 3 years has convinced me that there are three fundamental keys which we must utilize to motivate these landowners. The absence of any one of these keys will halt the Third Forest in its tracks.

"First, we must communicate with landowners on a personal basis. Eyeball to eyeball, we must tell them of the gravity of their forest management needs and the benefits they will reap therefrom.

"Second, adequate economic incentives must be provided.

"Third and last, services for accomplishing the needed work must be provided."

Chambers expressed the opinion that the mammoth job of forest improvements could be accomplished in a manner similar to the success story in agriculture. In Louisiana, he said, "For the period 1970-74, agricultural interests received $66.7 million annually in direct payments and price support loans to crop farmers, ranchers, and the like. That's 4 percent of the economic activity generated by the products these interests produce. . . ." He said forest improvements could be accomplished by investing a much smaller percentage of the total economic activity generated by the forests and forest products industry and the rewards would be astounding.

A summary of the literature shows occupation, residence, age, education, income, and amount of timberland owned as important determinants of participation in forest practices. Most small forest ownerships were in the hands of persons 50 years of age or older with 11 years of formal education or less. Forest practices as a whole were not used to any significant degree by owners of small timber tracts, with tree planting being the most used practice. Forestry is a long-range crop that produces many goods and services. Intensive forest management yields a high rate of return to society (the general public) but a low rate of return to the landowner.

Study Area

The forests of Louisiana fall into two broad categories. Softwood forests comprising the four major southern pines (loblolly, longleaf, shortleaf, and slash) occupy most of the uplands. Oak-hickory forests are also found where the pine has been removed from pine-hardwood forests. Hardwood forests are found principally on the alluvial flood plains in the Delta and along major streams elsewhere in the state. The major hardwood forests are made up of species typically found in the South, such as oak, gum, ash, hackberry, pecan, sycamore, willow, cottonwood, and cypress (a softwood).

Most of Louisiana was covered with virgin timber that was removed in the late 1800's and early 1900's. The largest sawtimber harvest in the history of the U.S. was made in Louisiana in 1913. Some of the clearcut land regenerated naturally, but much of it was taken over by farmers.

Three major study areas (Northwest, Southwest, and Southeast) were located in the upland pine areas. A determined effort was made by many people to grow agricultural row crops on the cleared uplands. However, the land was not as level or fertile as the bottomlands. Also, farms were not large in size and mechanization was not very feasible. The depression of the 1930's plus the decreasing economic situation of small farms resulted in much of the land being released from cultivation, and much of it reverted back to some type of timber production. Southern pines grow well on the hill soils. Site indexes (average height of dominant and codominant trees at age 50 years) of 85 to 100 are not uncommon on the better sites.

The Northwest Pine Area comprises the largest concentration of loblolly and shortleaf pine in the state. The topography is rolling with small and medium stream bottoms. Elevation is 100 to 600 feet. The softwood forests are loblolly pine and shortleaf pine. Bertrand (1960) used the term ''yeoman farmers'' to describe the inhabitants of the North Louisiana Uplands. He further classified the owners as hardy, independent, individualistic, and somewhat conservative in their approach to new ideas or practices.

In the Southwest Pine Area, longleaf pine, slash pine, and loblolly pine are the most common softwoods. Species of oak and gum are the most frequent hardwoods located in the low-lying areas. The topography ranges from rolling clay hills on the north to hardpan flatlands on the south. Sandy and clay loam soils are found in the coastal plains and prairies, while soils of the flatwoods and river terraces are predominantly silt loams. Rice, soybeans, forest products, and cattle are the main farm crops.

People living in the northwest part of the Southwest Pine Area are predominantly of English and Irish descent who worship in the Protestant faith and tend to live on the land they own. On the other hand, residents to the south are predominantly of French heritage and worship in the faith of Catholicism. Many Acadian customs and practices have been passed from generation to generation. These people tend to live in towns and cities.

The Southeast Pine Area (Florida Parishes) includes the pine forests of Louisiana located east of the Mississippi River. Major sources of income are from dairying, pastures, truck farming, and timber. All four major southern pines are found here, with longleaf pine and slash pine concentrated on the east side of the area and loblolly pine and shortleaf pine occurring on the west. Hardwoods occur throughout the area but are more abundant in the southern section. The topography ranges from rolling hills on the north to flatlands on the south. The area is made up of small farms with the majority of the owners living on the land.

Two major survey areas (North Delta, South Delta) were located in the bottomlands. The forests are hardwoods, with the exception of cypress. The most productive lands are located in these areas and in belts of varying width along waterways throughout the state. Farms are generally large, highly mechanized, and intensively managed for production of row crops and cattle. Much of the land that was in hardwood timber has been cleared in the past 15 years for agricultural use. Forests on nonindustrial ownerships are now essentially limited to land with poor physical properties or inadequate drainage.

The North Delta consists of the alluvial flood plains of north Louisiana and the Red River Valley. Soybeans, cotton, corn, cattle, and timber are the main cash crops.

The South Delta is made up of the alluvial flood plains of the Atchafalaya River and a part of the Mississippi River. This area plays an important role in the flood control program for the Mississippi River. Timber is the logical use for some of the land because of flooding and inadequate drainage. Farming, where feasible, is intensive. The main cash crops are sugarcane, soybeans, beef cattle, and timber.

Another survey area, the Industrial Area, includes the territory on each side of the Mississippi River from about 30 miles north of Baton Rouge to New Orleans, and the area surrounding portions of Lake Pontchartrain and Lake Maurepas. This area was separated from the others because of industrialization and the concentration of population. The opportunity for industrial employment is excellent and a job in industry is usually the main source of income. The soil and forest land vary in characteristics from those of the Southeast Pine to the South Delta areas, and include extensive hardwood bottomland forests and a sizeable area of flatwoods southern pine.

Methods and Procedures

This study included Louisiana residents who are owners of 20 to 500 acres of forest land. The sampling design was a stratified random sample to assure good representation. The state's timbered lands were stratified into six broad areas according to timber types, soils, agricultural crops, characteristics of the human population, and industrialization. Each of the six areas was then stratified into four subareas (Figure 2).

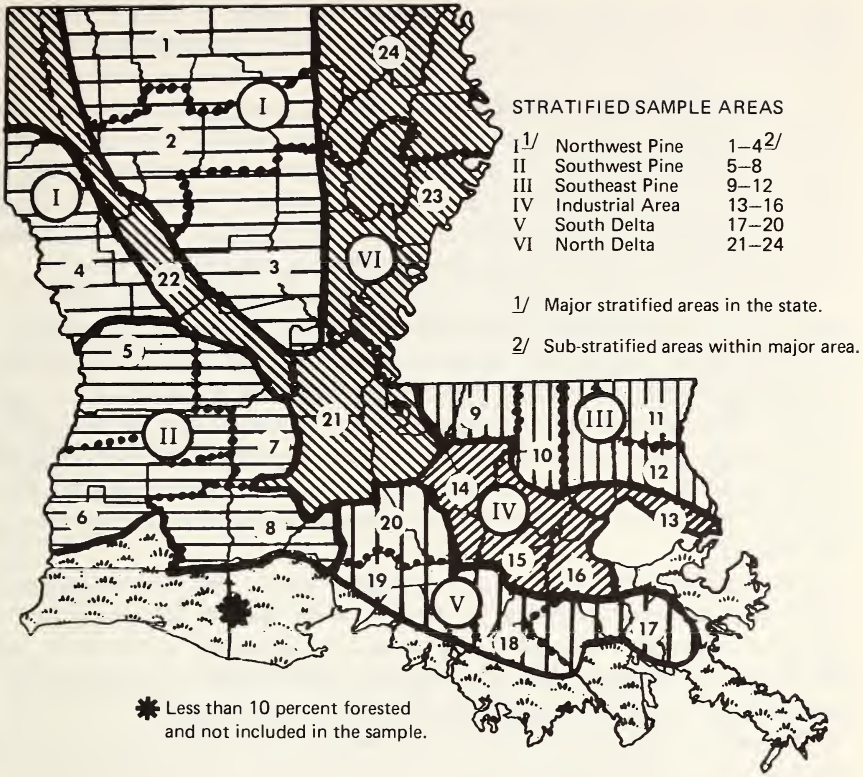

Figure 2.—Six major stratified and 24 sub-stratified areas of Louisiana from which random samples were drawn.

One voting ward was randomly selected in each of the 24 subareas. A random sample of 14 landowners, each owning between 20 and 500 acres of forest land, was then drawn from the tax rolls for each of the 24 subareas. Alternate owners were also randomly drawn to replace those failing to qualify on further study. The random procedure was used to assure an unbiased sample.

Each of the 336 owners (24 stratified areas x 14 interviewees per area) was personally interviewed. A member of the study team went to the sample areas and located interviewees through use of such means as description of the property, parish maps, telephone directories, public employees, and local citizens. Completion of a questionnaire (see Appendix) was accomplished in an informal manner to assure an atmosphere of ease and congeniality. A special effort was made to obtain facts and opinions from the owners without influence from the interviewer. Questions were asked to obtain information on characteristics of owners, information regarding forest management practices, and general data on their land and timber. The characteristics of owners studied were forest acres owned, participation in community organizations, occupation, annual income, age, number of years the owner had owned forest land, years of formal schooling, sex, residence at the time of the study, residence during most of the life of the interviewee, children in school, and race.

Information was obtained on forestry knowledge and practices by collecting data on what had been done in the past 10 years and what was planned for the coming 10 years in regard to forest land, tree planting, timber harvesting and selling practices, timber stand improvement, prescribed burning, policy on recreational use of forest land by the public, forest credit, opinion as to the need for improving the productivity of forest land in general, and the personal obligation that each interviewee felt he or she had, as an owner, to do something to improve the productivity of his or her forest.

Frequency distributions and the chi-square test of variance for goodness of fit were utilized in analyzing the data with the aid of a computer. A minimum expected value of five was used in testing for significance with the chi-square method. Each landowner characteristic studied was compared with the forest management practices listed above.

Information was also collected and frequency distributions were tabulated for total acres owned, primary and secondary uses of forest land, distance in miles that absentee owners who were Louisiana residents lived from the property, farming activity, main cash crop, and who managed the property.

Results

Land Use.—Information on primary and secondary uses of forest lands was obtained by providing interviewees with a list of five land uses from which he or she identified the primary and secondary uses of forest lands on the date of the interview.

More than half of the owners in the sample listed timber growing as the primary use of their forest land (Table 1). Approximately half of those listing timber growing as the primary use showed no secondary use, and it is this group that should be most responsive to an intensive forest management program. The remainder of the owners showing timber growing as the primary use but also listing a secondary use would probably be receptive to a management program that would help the owner in reaching his objective. Grazing by domestic animals was the primary use of forest land listed by 60 owners, and wildlife was listed by 53 respondents.

Table 1.—Primary use of forest land

Use	Owners in sample		Estimated total owners in La.
	Number	Percent	
Timber growing	187	55.7	62,478
Grazing	60	17.9	20,047
Wildlife	53	15.8	17,707
Other	21	6.3	7,016
Recreation	15	4.3	5,012
Total	336	100.0	112,260

Table 2.—Secondary use of forest land

Use	Owners in sample		Estimated total owners in La.
	Number	Percent	
No specified secondary use	95	28.3	31,740
Wildlife	80	23.8	26,729
Timber growing	66	19.6	22,051
Grazing	58	17.3	19,378
Recreation	25	7.4	8,353
Other	12	3.6	4,009
Total	336	100.0	112,260

The leading secondary uses were wildlife, timber growing, and grazing (Table 2). These owners would probably be receptive to a management program compatible with their primary and secondary uses of forest land.

Future Plans for Forest Land.—In the section of the questionnaire dealing with forest land management, each interviewee was asked: What plans do you have for your woodlands in the next 10 years? The interviewees were not given a list from which to select an answer. Each owner's reply was recorded and considered to be the actual plans he had in mind and would apply to the land. Replies were grouped into the six categories shown in Table 3, and are listed in order of frequency by size of ownership. These data show that more than half the owners plan to let unaided nature produce what goods and services it can, with the main function of the owners being to either store, harvest, or sell what is produced. This applies to primary and secondary uses of forest land. It includes the ownership group planning to let timber grow without management, and those with no plans. In both cases, the land will remain in timber and production will be left to ''Mother Nature.''

A fifth of the owners planned to do something to improve the productivity of their forest land by using management practices such as thinning, timber stand improvement[2], prescribed burning, plowing fire lines, and

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[2] Timber stand improvement (TSI) in this study refers to improving the productivity of forests by removing cull trees.

Table 3.—Future plans of owners for forest lands, by size of ownership

	Acres of forest land								Total owners in sample	
	20-40		41-80		81-200		201-500			
Future plans	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Grow timber as is (without management)	43	44	30	33	30	37	20	31	123	36.6
Manage forest	7	7	16	17	22	27	26	41	71	21.1
No plans	27	28	22	24	12	15	5	8	66	19.6
Clear land	13	13	11	12	11	13	6	9	41	12.2
Other	7	7	11	12	6	7	6	9	30	8.9
Wildlife	1	1	2	2	1	1	1	2	5	1.5
Total	98	100	92	100	82	100	64	100	336	99.9

planting. The number of improvement practices averaged 2.8 per owner. These forest lands will be managed, but, on the average, not intensively managed.

Twenty-one percent of the interviewees did not list timber production as either a primary or secondary use of their forest lands. Included were 41 owners (12 percent) who planned to clear their land, and 30 (9 percent) who had "other" plans for their forest lands. On a statewide basis, this means an estimated 13,471 owners of small tracts of timber plan to remove the forest from their lands in the next 10 years. The only contribution to the wood supply will be the volume removed, and the values of the lands as forests will terminate at the time of cutting. An estimated 10,103 additional owners plan to keep their lands in forests, but rank wood production as a third or lower priority use. These forests will continue to make good contributions to amenity values, but only a minimum contribution to the wood supply.

Only five owners (1.5 percent) had plans to manage their timber holdings primarily for wildlife in the next 10 years, compared with 53 (15.8 percent) who had listed wildlife as the primary use of their forest lands a few minutes earlier in the same interview. Almost all of these ownerships were not being managed at the time of the interview and the owners were going to leave the management in the hands of "Mother Nature" during the next 10 years.

Even though owners of small tracts of timber in Louisiana are not doing much in the way of management, 70 percent of them show a definite multiple-use orientation in that the land is usually being used for more than one purpose. Also, under present plans for the future, the production of wood will be either a primary or secondary use of more than 75 percent of the ownerships and 85 percent of the land area in small ownerships.

Forest Acreage.—There was a highly significant relationship ($P<.01$)[3] between the acreage of forest land owned and future plans for the forest, plans for thinning and timber stand improvement, frequency of timber sales, and payment of the entire cost of a forest improvement practice. Plans for prescribed burning were significantly associated ($P<.05$) with forest acres owned.

The relationship between acres of forest land owned and future plans for the forests is shown in Table 4. The percentage of owners planning to do some forest management work increased with increasing size of ownership. The percentage of owners with plans to let unaided nature produce the timber, and owners with no plans whatsoever for their forest holdings, decreased with increasing size of ownership.

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[3] Highly significant ($P<.01$) and significant ($P<.05$) are used in discussing the results of this study in the normal way for expressing research findings. A minimum expected value of five was used in testing for significance with the chi-square method.

Table 4.—Relationship between size of ownership and selected forest practices, by number of owners

Acres of forest land owned	Plans for thinning		Plans for TSI[1]		Sold timber in past 10 years	
	Yes	No	Yes	No	Yes	No
20 to 40	35	63	8	82	43	55
41 to 80	32	60	11	80	36	55
81 to 200	44	38	13	69	53	29
201 to 500	38	26	23	41	49	15
Total[2]	149	187	55	272	184	154

[1] Timber stand improvement, including cull tree removal.

[2] In some tables and summaries, the total number of interviewees shown is slightly less than 336. This is due either to a refusal by some interviewees to reply to the question or the interviewers' failure to request or record the information.

Only a third of the 190 owners with 20 to 80 acres of forest land had plans for conducting a thinning practice in the next decade. On the other hand, 44 (54 percent) of the 82 owners in the 81- to 200-acre category had plans for thinning, and 38 (59 percent) of the 64 landowners in the 201- to 500-acre ownership class had plans for conducting a thinning practice (Table 4). The percentage of owners who had plans for timber stand improvement increased with the acres of forest land owned. For example, only 8 (9 percent) of the 90 owners who owned 20 to 40 acres had plans for timber stand improvement in the next 10 years, while 23 (36 percent) of the 64 owners who owned 201 to 500 acres had such plans (Table 4).

In general, the percentage of owners who had sold timber in the past 10 years increased with acres owned (Table 4). The largest ownership class had sold timber about twice as often as the smallest. The same pattern held true for plans to sell timber in the next 10 years.

Involvement in Community Organizations.—Membership of interviewees in community organizations was as follows:

Memberships in organizations	Owners	
	Number	Percent
0	127	38
1 to 3	158	47
4 or more	51	15
Total	336	100

Membership in community organizations had a highly significant association with interest in long-term leasing. Also, a significant association

Table 5.—Relationship between membership in community organizations and selected forest practices, by number of owners

Memberships in organizations	Interest in leasing		Feelings on increasing forest productivity		
	Yes	No	Must	Should	Not important
0	9	118	23	79	23
1 to 3	20	138	31	107	14
4 or more	13	38	15	33	3
Total	42	294	69	219	40

was found in regard to need for increasing the productivity of forest lands, main use of forest land, future plans for forest land, and owners having planted trees.

Forty-two (13 percent) of the owners were interested in a long-term lease (25 years or more). Owners associated with up to three organizations were almost twice as interested, and owners associated with four or more organizations were more than three times as interested in leasing as were nonmembers (Table 5).

Sixty-nine (21 percent) of the owners thought forest lands *must* be more productive, 219 (67 percent) felt forest lands *should* be more productive, and 40 (12 percent) of the owners cited productively as *desirable but not important*. No one listed production as *not desirable*. Owners said forest lands either must or should be more productive almost twice as often when they belonged to community organizations. More than half the owners who cited forest productivity as unimportant did not belong to any community organization (Table 5).

A higher percentage of owners involved in community organizations listed timber production as the main use for their forest lands while a higher percentage of owners not participating in community organizations listed grazing.

Regarding future plans for forest lands, nonmembers of community organizations had plans to clear their forest land 2.5 times as often as members. Also, a larger percentage of nonmembers had no plans for their forest lands.

While only 37 (11 percent) of the interviewees had planted trees in the past, there was a significant association between membership in organizations and having planted trees. Owners who were members of up to three organizations had planted trees twice as frequently, and members of four or more organizations had planted trees three times as frequently, as nonmembers.

Occupation.—Landowners interviewed were classified into seven occupational groups:

Occupation	Owners	
	Number	Percent
Retired	95	28.4
Wage and salary earners	76	22.7
Professional	60	18.0
Farmers	43	12.9
Self-employed	42	12.6
Miscellaneous	11	3.3
Unemployed	7	2.1
Total	334	100.0

Occupation was found to have a highly significant association with plans for thinning and plans for fencing (constructing a fence around the property). Occupation had a significant association with paying the entire cost of a forest improvement practice, interest in forest credit, production of forest land, and plans for cull tree removal. Owners who were self-employed or in professional occupations were the groups most interested in thinning their timber stands, while farmers showed the least interest in this forest practice (Table 6). Seventy-two (22 percent) of the owners had plans for fencing. Wage earners, unemployed, professional, and self-employed owners showed more interest in fencing than did farmers, retired, and miscellaneous owners.

Thirty-seven (11 percent) of the owners had planted trees in the past 10 years. Most of the planting had been done by those in the professional, retired, and self-employed occupational groups. Little planting had been done by farmers and miscellaneous owners. No planting had been done by the unemployed (Table 7).

Owners with plans to plant trees exceeded those who had planted trees by 41 to 37. Occupation was significantly related to plans to plant trees, with professional and self-employed owners having the most interest in this activity. Farmers and retired owners had the least interest in planting trees (Table 7).

Occupation was significantly related to the willingness of owners to invest funds in a forest improvement practice without some type of financial help. Fifty-five (16 percent) of the interviewees had participated. Owners in the self-employed and professional groups were the leaders in this activity while those in miscellaneous and unemployed categories had not participated (Table 7).

Almost a fifth of the owners expressed a desire to obtain forest credit at a reasonable rate of interest to improve the productivity of their forest holdings. The desire was rather uniform among all occupational groups, except the miscellaneous and retired owners.

Table 6.—Views of landowners on thinning, fencing, and leasing, by occupational categories

	Plans for thinning				Plans for fencing				Interested in a long-term lease			
	Yes		No		Yes		No		Yes		No	
Occupation	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Wage earner	34	45	42	55	26	34	50	66	15	20	61	80
Professional	32	53	28	47	16	27	44	73	12	20	48	80
Farmer	14	33	29	67	7	16	36	84	5	12	38	88
Retired	36	38	59	62	10	11	85	89	6	6	89	94
Self-employed	24	57	18	43	10	24	32	76	4	10	38	90
Miscellaneous	5	46	6	54	1	9	10	91	0	0	11	100
Unemployed	3	43	4	57	2	29	5	71	0	0	7	100
Total	148	44	186	56	72	22	262	78	42	13	292	87

Table 7.—Views of landowners on tree planting and owner-paid improvements, by occupational categories

	Trees already planted				Plans for planting trees				Paid entire cost for a forest improvement practice			
	Yes		No		Yes		No		Yes		No	
Occupation	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Wage earner	4	5	72	95	12	16	65	84	9	12	67	88
Professional	11	18	49	82	14	23	46	77	16	26	45	74
Farmer	2	5	41	95	1	2	42	98	6	14	36	86
Retired	11	11	85	89	6	6	88	94	11	12	83	88
Self-employed	8	19	34	81	7	17	35	83	13	31	29	69
Miscellaneous	1	9	10	91	0	0	11	100	0	0	11	100
Unemployed	0	0	7	100	1	14	6	86	0	0	6	100
Total	37	11	298	89	41	12	293	88	55	16	277	84

Occupation was significantly associated with personal feelings of owners regarding the need for increasing the productivity of forest lands. Two hundred eighty-seven (88 percent) of the owners of small tracts of timber felt forest lands either must or should be made more productive, while only 40 (12 percent) cited productivity as desirable but not important. Owners in the professional, self-employed, and wage earner categories placed more emphasis on the need for increasing the productivity of forest lands than did other occupational groups.

Owner Income.—Information was solicitated concerning annual income because of its close association with funds available for investment. Data were obtained from 304 (90 percent) of the interviewees. The results follow:

Annual income (dollars)	Owners	
	Number	Percent
Less than 2,000	25	8.2
2,000 to 4,000	45	14.8
4,001 to 7,000	58	19.1
7,001 to 10,000	36	11.8
10,001 to 15,000	58	19.1
15,001 to 25,000	43	14.1
More than 25,000	39	12.8
Total	304	99.9

Annual income had a highly significant association with feelings of interviewees on the need for increasing the productivity of forest lands. For example, 166 (95 percent) of the landowners who earned more than $7,000 annually thought forest lands either must or should be more productive, while 9 (5 percent) cited productivity as desirable but not important. In contrast, 96 (79 percent) of the landowners who earned less than $7,000 a year thought forest lands either must or should be more productive, and 26 (21 percent) felt productivity was desirable but not important.

Income also was significantly associated with the landowner's feeling of personal obligation for making lands under his control more productive. Owners with higher incomes felt a stronger obligation to do something about increasing production than did owners with lower incomes.

There was a highly significant association between tree planting and annual income. Landowners who earned $7,000 to $10,000 and those who earned more than $25,000 had done most of the tree planting, while owners who earned less than $7,000 had done the least. Income also was associated with the landowner's plans for planting. For example, 87 percent of the owners with plans to plant trees in the next 10 years had an annual income of more than $7,000.

Income was significantly related to the landowner's interest in a long-term lease. Generally, landowners who earned less than $10,000 had little interest in a long-term lease, while almost a fourth of the landowners who earned $10,000 and more were interested in leasing.

Income was significantly associated with the owner's plans for fencing, with most of the interest in fencing being concentrated in the higher income groups. Only 16 (12.5 percent) of the 128 landowners with incomes of less than $7,000 expressed plans to fence their lands. Twenty-eight (30 percent) of the 94 middle-income earners ($7,000 to $15,000) planned to invest in fences. Seventeen (21 percent) of the 82 owners with annual incomes of more than $15,000 had plans for fencing their lands.

Seventy-nine percent of the owners supported up to three people with their incomes, while 21 percent supported from four to nine persons.

Age of Owner.—The youngest owner in the sample was 27 and the oldest was 92. The most frequent age was 65, with 15 owners of that age. The average age of all owners was 59. The greatest number of owners (108 or 32 percent) were in the 60-to-69 age group. The number of owners by age group was as follows:

	Owners in sample		Estimated total owners
Age group	Number	Percent	in Louisiana
20-29	4	1	1,123
30-39	23	7	7,858
40-49	53	16	17,962
50-59	79	24	26,942
60-69	108	32	35,923
70-79	48	14	15,716
80-89	16	5	5,613
90-92	4	1	1,123
Total	335	100	112,260

Age of owner had a highly significant association with plans for cull tree removal, plans for fencing, plans for prescribed burning, and attitudes toward the importance of increasing the productivity of forest lands. Thirty percent (102) of the landowners had plans for removing cull trees, and most of these owners were less than 60 years of age. Most of the interest in fencing was shown by owners less than 50 years old.

A third of the 76 landowners in the 30-to-49 age group had plans for prescribed burning. This age group showed about twice as much interest in prescribed burning as did the older owners. In general, the younger owners expressed a stronger desire for an increase in the productivity of forests than did older owners. However, it was encouraging to note that a high percentage of all age groups recognized a need for increasing the rate of production on small forest holdings.

Tenure of Ownership. — The years of ownership of forest land was as follows:

Years of ownership	Owners	
	Number	Percent
Less than 11	57	17
11 to 25	108	32
26 to 50	139	41
More than 50	29	9

There was a highly significant relationship between length of tenure and the opinions of owners concerning the importance of increasing the productivity of their forest lands and plans for planting trees. Most landowners in every tenure group said their forest lands either must or should be more productive. However, the greatest interest in increasing production and in planting trees was shown by owners with the shortest length of tenure (the younger owners). Most of the owners (73 percent) had purchased all of their land, while 27 percent had acquired at least a part of their ownership by inheritance. Eighteen percent of the owners had a mortgage on the property.

Education of Owners. — The years of formal education of the respondents was sampled and the results follow:

Years of education	Owners	
	Number	Percent
None	5	1.5
1 to 4	8	2.4
4 to 8	67	20.0
9 to 11	69	20.6
12	47	14.1
13 to 15	55	16.5
16	43	12.9
More than 16	40	12.0
Total	334	100.0

There were 13 (4 percent) of the owners who had not completed the fourth grade, 67 (20 percent) who had quit school between the fourth and eighth grades, and 69 (21 percent) who had ended their formal education between the ninth and eleventh grades. Out of 185 owners who had completed high school, 138 (75 percent) had attended college and 83 of them had graduated. Almost half of the college graduates had taken courses in graduate school.

Formal education had a highly significant relationship to the importance owners placed on the need for increasing the production of forest lands, to plans for timber stand improvement, and to forest improvement practices completely financed by the owner. Education had a significant relationship to plans for prescribed burning, recreational use of the property, and the personal obligation felt by the owner for improving the productivity of woodlands.

A higher percentage of the interviewees with a formal education of high school or above said forest lands either must or should be made more productive than did those having less formal education. In general, the importance attached to improving the productivity of forest lands increased with education.

Education was associated with landowners who had paid for some type of forest improvement practice. Fifty-five (16 percent) of the interviewees had completed one or more practice in which they had paid the entire cost. Owners with a high school education and above had participated more than twice as frequently as owners with less formal education.

Seventy-one (38 percent) of the owners with at least a high school education had plans for timber stand improvement, compared with 31 (21 percent) of the owners with less formal education.

Race. — There was a highly significant difference of opinion between the white and black races regarding the need for increasing the productivity of forest land and a significant difference in main use of forest land. White owners placed more emphasis on the importance of increasing the productivity of forests, while more black owners listed grazing as the primary use of their forest lands.

Sex of Owner. — Of the landowners interviewed, 288 (86 percent) were males and 48 (14 percent) were females. There are an estimated 96,552 males and 15,718 females who are owners of small tracts of timber in Louisiana. No significant relationship was found between the sex of owners and the forest practices included in this study. However, female owners were more interested in leasing and rated the importance of increasing the productivity of forest lands higher than did male owners.

Residence in the Past. — Landowners were questioned about their place of residence during most of their lives. The purpose was to provide a comparison of landowners from rural and urban environments. Rural residents outnumbered urban residents 234 to 100. Residence during most of the life of the owner had a highly significant relationship to plans for planting trees and to interest in entering a long-term lease. Also, it had a significant association with main use of and future plans for woodlands, recreational use by the public, and the importance attached to increasing the production of forest lands.

Forty-one (12 percent) of the owners had plans to plant trees. Owners with urban backgrounds had plans to plant trees more than twice as often as owners with rural backgrounds. Also, owners with plans to plant trees exceeded those who had planted trees by 10 percent. The entire increase came from owners with urban backgrounds. In addition, respondents with urban backgrounds were twice as interested in a long-term leasing agreement as were those with rural backgrounds.

More rural owners used their land primarily for grazing and they were somewhat less willing than urban owners to allow public use of their forest land for recreation. Owners from urban areas had plans to practice some forest management more often than did rural owners. Also, the importance placed on the need for increased productivity was higher among urban owners.

Present Residence. — Along with past residence of a landowner, the location where the landowner currently lived was also found to be an important characteristic. Interviewees were asked if their home was located on their woodland. One hundred sixty-two (48 percent) of the owners lived on some part of their forests, while 174 (52 percent) were absentee owners.

Absentee owners were asked the distance in miles they lived from their woodland. Most (52 percent) of the absentee owners lived within 10 miles, 43 percent were within 50 miles, and 5 percent were more than 50 miles from their property. The results were as follows:

	Owners	
Miles from woodland	Number	Percent
10 or less	90	51.7
11 to 50	75	43.1
51 to 200	8	4.6
200 or more	1	0.6
Total	174	100.0

Residence had a highly significant relationship with plans for constructing fire lines, fencing, and with interest in leasing forest land. Resident owners were more interested in constructing fire lines and fencing, while absentee owners indicated an interest in leasing their lands that exceeded that of resident owners by 30 to 12.

Plans for planting trees and for the main use of forest land were significantly associated with place of residence. A total of 41 (12 percent) of the interviewees had plans for planting. Absentee owners with plans for planting trees exceeded resident owners by 28 to 13. Ninety-nine (61 percent) of the owners who lived on their woodlands listed timber growing as the main use of their forest lands, compared with 88 (51 percent) of the absentee owners. Thirty-six (22 percent) of the resident owners used their forest lands primarily for grazing, compared with 24 (14 percent) of the absentee owners. Absentee owners listing wildlife as their main use of forest lands outnumbered resident owners 36 to 17.

Children in School. — More than half (61 percent) of the landowners had no children attending school. The presence of school-age children in the home had a highly significant association with the owner's personal feelings on the need for increasing the productivity of forest lands, and significant associations with prescribed burning, interest in obtaining forest credit, plans for fencing, and plans for constructing fire lines. A higher percentage of the owners with children in school showed interest in the above activities than did owners without children in school.

Obligations of Owners in Forest Management.—Two questions were included in the questionnaire to find out how owners of small tracts of timber viewed the importance of forest management. The first question was designed to obtain a general impression of how productive forest lands should be in the opinions of owners of small tracts of timber. Seventy-one owners said forest lands must be more productive, 224 said forest lands should be made more productive, and 41 said increasing productivity was desirable but not important. None of the respondents rated increasing the productivity of forest lands as undesirable.

Immediately after obtaining the opinions of owners concerning the general importance of increasing the productivity of forest lands, interviewees were asked what they considered their personal obligations to be for doing something about increasing the productivity of the forest lands they own. Five percent of the owners felt it was essential, and 11 percent thought it was important that they, as owners, should do something to increase the productivity of their forest lands even though it would not be profitable. More of the owners (37 percent) felt a personal obligation to increase production if it were profitable, and an additional 33 percent if it were profitable and convenient. Of all interviewees, 88 percent felt some type of moral obligation to make forest lands more productive, while 12 percent felt no obligation. The percentage of owners that felt no personal obligation was the same as the 12 percent planning to clear their forest lands.

Use of Forest for Recreation. — It was encouraging to find that 74 percent of the owners of small forest tracts were willing for the public to use their property for recreational purposes. Permission of the owner was the most frequent requirement. Urban owners were more willing to allow public use of their forest land for recreation than were rural owners. Feelings of owners were as follows:

	Percent owners by residence		All owners	
Public use of land	Rural	Urban	Number	Percent
Without pay or permission	16	27	65	19.3
Permission only	51	46	166	49.4
Only with pay	4	8	18	5.4
None	29	19	87	25.9
Total	100	100	336	100.0

Forest Management Practices.—Much information was obtained concerning timber management practices being used by owners of small tracts of timber. Ninety percent of the owners made their own decisions regarding forest management practices, while 10 percent had delegated this responsibility to others. Only 5 percent—17 of 336 owners in the sample—had a written management plan. Fourteen percent had talked with a forester about a management plan and 8 percent had obtained some assistance from a forester on a management plan. When asked why they had not made more use of foresters in preparing management plans, owners gave such reasons as (1) low rate of return from forestry, (2) long period of production, (3) small acreage, and (4) they preferred to handle their forests themselves.

Fifty-three percent, or 177 of the owners, had sold timber within the last 10 years. When asked why they sold timber, 32 percent said they wanted the income and the timber needed thinning, 27 percent said they needed the money, and 10 percent said the timber cutter needed a job. Only 7 percent, or 13 owners, had done part of the harvesting.

Thirty-one percent of the owners had the timber marked, and 27 percent had a written contract with the buyer. Fifty-one of the owners obtained bids on their timber, with 75 percent of these obtaining three or more bids. Forty-two of the 51 owners that obtained bids said they chose the buyer that offered the highest price.

Sixty-five percent (119) of the 177 owners who had sold timber knew the price of stumpage before selling. As to payment, 68 percent were paid on the basis of the volume harvested, while 30 percent received a lump-sum payment for the timber included in the sale. Seventy percent were paid either as the cutting progressed or after the cutting was done, and 21 percent were paid before the cutting. Thirty percent of the owners knew how much money they would receive from the sale before the timber was cut.

Most owners (86 percent) expressed satisfaction with the sales. Half of those gave the reason that they had received the income expected. However, 14 percent of the sellers said they were either cheated by the buyers or the uncut timber was heavily damaged by destructive logging practices of the cutter. Owners who had not sold timber said their timber was not ready to be cut, or they were not ready to sell their timber. Forty-four percent of the owners who indicated they intended to sell timber in the next 10 years said they would obtain bids, while 25 percent said they would deal with only one buyer.

The 336 owners of small tracts of timber gave many reasons for not using more forestry improvement practices. Thirty-six percent listed lack of sufficient knowledge of forestry practices to make a profit, 12 percent replied that they had more profitable uses for their money and time than timber growing, and 9 percent said their holdings were too small. Other reasons given were that they were too busy, funds were not available, it takes too long to grow trees, and prices for timber products were too low to justify investing more time and money in forestry.

When asked what was needed to get more intensive forestry practiced, 37 percent of the respondents indicated a need for an intensive and professional program involving technical and financial assistance, 12 percent said better timber prices were needed, and 22 percent said they did not know how to get owners of small tracts of timber to practice more intensive forestry.

No agricultural farming activities were being carried out on 61 percent of the ownerships. This means that 205 owners in the sample, and an estimated 68,479 owners in the state, are not engaged in agricultural farming activities. The entire holdings of these owners are available for either forest management or a forest-related use.

There were 131 ownerships, 39 percent of the total, on which farming activities were being conducted. The farming was actually being done by 70 owners, while 61 owners either rented or leased their agricultural lands. The income received was of sufficient importance to 86 owners for them to list farming as their main source of income. The usual source of income was from row crops, livestock, or rental payments. The remaining 45 owners did not receive their main income from agricultural activities.

Ninety percent of the 131 ownerships where farming was an activity had received agricultural conservation program payments for farm practices in the past 10 years, compared with only 9 percent of the 336 owners in the sample who had obtained ACP payments for improving forestry practices. This indicates that conservation programs involving agriculture have been far more attractive to owners of small tracts of timber than have those involving forestry.

Differences Between Owners of Pine and Hardwood Forests.— There were highly significant differences between owners of pine forests and hardwood forests in 10 of 16 variables tested, and significant differences in two additional variables.

The highly significant differences were in main use of forest lands, plans for woodlands, thinning, removing cull trees, fire lines, prescribed burning, fencing, sale of timber in the past 10 years, recreational use of forest land, and personal obligation for improving the productivity of forest lands. The variables showing significant differences were interest in forest credit and payment of the entire cost of a forest improvement practice.

The production of wood was the main use listed by 56 percent of the owners (187 of 336) on a statewide basis and was the leading use in both the pine and hardwood areas. However, 79 percent of the owners of pine were using their forests primarily for wood production, compared with only 32 percent of the owners of hardwoods (Table 8).

Table 8.—Main use of forest lands by pine and hardwood owners

	Pine owners		Hardwood owners		Total owners	
Main use	Number	Percent	Number	Percent	Number	Percent
Forest	133	79	54	32	187	56
Grazing	20	12	40	24	60	18
Wildlife	9	5	44	26	53	16
Recreation	3	2	12	4	15	4
Other	3	2	18	6	21	6
Total	168	100	168	100	336	100

Grazing was the main use of forest land shown by 60 owners (18 percent), and wildlife management was listed by 53 (16 percent). Owners of hardwood forests listed grazing as the main use of their land twice as often, and listed wildlife management five times as often, as did owners of pine forests. Recreation was the main use listed by 15 owners, with 12 (80 percent) of them being in the hardwood area (Table 8).

More than three times as many landowners living in the pine areas were planning to use forest practices as were owners of hardwood forests (Table 9). Of 41 landowners who planned to clear the forests from their lands, 32 of them were in the hardwood areas. Also, four of the five landowners listing wildlife as the main use of their woodlands in the future were in hardwood areas. There were 59 owners of hardwoods without any plans for their forests, compared with seven owners of pine forests.

One hundred and four (70 percent) of the owners of pine forests had plans for thinning in the next 10 years, compared with 45 (30 percent) of the owners of hardwood forests. More owners of pine forests had plans for removing cull trees than did owners of hardwood forests. Owners of pine

Table 9.—Plans for woodlands in pine and hardwood areas

Plans for woodlands	Owners in pine area		Owners in hardwood area		Total owners	
	Number	Percent	Number	Percent	Number	Percent
Grow timber without management	92	55	31	19	123	37
Forest management practices	54	32	17	10	71	21
Clear land	9	5	32	19	41	12
No plans	7	4	59	35	66	20
Other	5	3	25	15	30	9
Wildlife	1	0.6	4	2	5	1
Total	168	99.6	168	100	336	100

forests with plans for constructing fire lines exceeded owners of hardwoods by 45 to 7. As expected, activity in prescribed burning was centered with owners of pine forests, with slightly more than a fourth of the pine owners having plans for prescribed burning. Owners had plans for fencing twice as often in pine as in hardwood areas.

More than half (54 percent) of all owners in the survey had sold timber in the past. One hundred and ten (65 percent) of the owners of pine forests had sold timber, as compared with 71 (42 percent) of the owners of hardwood forests.

Owners of hardwood forests ranked the importance of increasing the productivity of their forest lands lower than did owners of pine forests. Thirty-six of the 44 owners who felt no moral obligation to make their forests more productive were owners of hardwood forests.

Owners of pine forests allowed public recreational uses of their lands without payment or permission more frequently than did owners of hardwoods. Landowners in hardwood areas permitting use of their forest lands only with payment exceeded owners in the pine areas by 14 to 4. Also, more owners of hardwood forests did not allow the public to use their lands for recreational purposes (Table 10).

Table 10.—Policy on use of forest for recreation in pine and hardwood areas

Recreational use	Owners in pine area		Owners in hardwood area		Total owners	
	Number	Percent	Number	Percent	Number	Percent
Without payment or permission	45	27	20	12	65	19
Permission only	56	51	80	48	165	49
Only with payment	4	2	14	8	18	5
No public use	33	19	54	32	87	26
Total	168	100	168	100	335	100

Fifty-eight (17 percent) of the owners expressed interest in forest credit, with almost two-thirds of them owning land in pine areas. The entire cost of a forest improvement practice had been paid by 55 owners, with pine owners outnumbering hardwood owners by 36 to 19.

Summary

Forests are one of Louisiana's great renewable resources. Forty-seven percent (14.5 million acres) of Louisiana land is in forests. Louisiana's forest lands produce the raw material for 316 primary wood-using facilities in the state. The forests and forest product industries are the largest employers of industrial workers in Louisiana. With more than 32,000 employees in 1976, these industries paid approximately $129 million to landowners for stumpage and provided payrolls of about $370 million. Personnel of the Louisiana Cooperative Extension Service estimated $2.8 billion of economic activity was generated in 1976 by harvesting, processing, selling, transporting, and using wood and wood fiber produced in Louisiana. In addition, Louisiana forest lands produce other values and uses, including aesthetics, environmental quality, soil stabilization, recreation, water, and wildlife.

Louisiana has favorable environmental conditions for forest production. Forest lands of the state have the capacity for more than double current production and could meet estimated future demands if all forest lands were intensively managed. Also, it is the written policy of the state to protect, conserve and replenish its forest resources.

The ownership of small, nonindustrial timber tracts in Louisiana, some problems associated with such ownerships, and characteristics of owners have been examined in detail in this study.

The existence of problems associated with ownership of small tracts of timber was made evident by the results of several state, regional, and nationwide surveys. These studies found that a major portion of the small forests were in a low state of productivity and only a small percentage of the owners were applying forest management practices. In Louisiana, there are about 112,260 forest owners with holdings less than 500 acres in size, and they own 5,279,546 acres, or 40 percent, of the forest land. They account for more than 98 percent of all forest owners and they, along with 2,423 other nonindustrial owners with 2.8 million acres (average size: 1,181 acres), hold the key to the future supply of goods and services produced by forests in Louisiana. These forests are producing at less than half of their capabilities.

Information was solicited from a stratified random sample of Louisiana residents who owned small tracts of timber by means of personal interviews completed from July 1971 through July 1974. Questions were asked to obtain information on personal characteristics of owners, information regarding forest management practices, and general data on their land and timber. The personal characteristics of owners studied were forest acres owned, participation in community organizations, occupation, annual income, age, years the owner had possessed forest land (tenure), years of formal education, sex, residence during most of the life of the interviewee, residence at the time of the study, children in school, and race.

Information was obtained on forestry knowledge and practices by collecting data on what had been done in the past 10 years and what was planned for the coming 10 years in regard to: (1) main use of forest land, trees planted, and timber sold; (2) plans for the woodlands, planting trees, selling timber, timber stand improvement, plowing fire lines, prescribed burning, and building fences; (3) policy on recreational use of forest land by the public, interest in forest credit, opinion as to the need for improving the productivity of forest land in general, and the personal obligation that each interviewee felt he or she had, as an owner, to do something to improve the productivity of his or her forest.

Each of the 12 landowner characteristics studied was compared with the 14 forest management related practices listed above to test for significant relationships. A minimum expected value of five was used in testing for significance with the chi-square method.

Information was also collected on total acres owned, primary and secondary uses of forest land, distance in miles that absentee owners but residents of Louisiana lived from the property, farming activity, main cash crop, and who managed the property.

Forest Acreage.—The acreage of forest land owned had a highly significant association with future plans for the forest, plans for thinning, timber stand improvement, frequency of timber sales, and owners who had paid the entire cost of a forest improvement practice. Plans for prescribed burning were significantly associated with forest acres owned. In general, interest in the above activities increased with size of ownership.

Seventy-three percent of the owners had purchased all of their forest lands, while 27 percent had received part of their ownership by inheritance. Eighteen percent of the owners had a mortgage on the property.

Under present plans of owners, production of wood and wood fiber will be an important use of more than 75 percent of the ownerships and 85 percent of the land area in small ownerships in Louisiana in the future. The primary loss of acres will be through land clearing for row crops and pasture.

Occupation.—Occupation of the owner had a highly significant relationship to plans for thinning and fencing, and a significant association with interest in a long-term lease, trees planted, plans for a forest improvement practice, interest in forest credit, the importance attached to increasing production of forest land, and plans for cull tree removal. Owners in the retired, professional, and self-employed categories (48 percent of the interviewees) were more inclined to use their forest land primarily for timber production, whereas farmers and young owners were more likely to list grazing as the priority use for forest land, or a combination of timber production and grazing. Professionals were more likely than owners in other occupational groupings to have plans to initiate forest improvement practices. In the pine areas, owners in the professional, self-employed, and wage-earner categories were more interested in prescribed burning than were retired owners and farmers.

Annual Income.—One of every four owners had an annual income of less than $4,000. Income had a highly significant association with personal feelings of interviewees on the need for increasing the productivity of forest lands and with their having planted trees. The owners' feelings of personal obligation for making their forest lands more productive, plans for planting trees, fencing, and interest in leasing their lands were significantly related to income. In general, expressed interest and participation in the above activities increased with income.

Age.—More than half of the owners were more than 60 years of age, and this characteristic had a highly significant association with plans for cull tree removal, plans for fencing, prescribed burning, and the importance attached to increasing the productivity of forest lands. In general, the younger owners expressed more interest in the above activities than did older owners, but the older owners had most of the land. Also, age of owner had a significant association with main use of forest land, with a higher percentage of the younger owners listing grazing as the main use of their forests. The average age of all owners in the sample was 59.

Tenure.—Half of the interviewees had owned timber land more than 25 years. There was a highly significant relationship between length of tenure and the opinions of owners concerning the importance of increasing the productivity of their forest lands and their plans for planting trees. Most owners in every tenure group said their forest lands either must or should be more productive. However, the greatest interest in increasing production and in planting trees was expressed by the owners with the shortest length of tenure (the younger owners).

Education.—Formal education had a highly significant association with the importance owners placed on the need for increasing the production of forest lands, plans for timber stand improvement, and forest improvement practices completely financed by the owner.

Education had a significant association with plans for prescribed burning, recreational policy of the owner, and with feelings of personal obligation to do something to increase the productivity of their forest lands. In general, interest and participation in the above activities increased with years of formal education. Also, owners with a formal education of high school or above expressed the most interest in increasing the productivity of their forests.

Sex of Owner.—No significant relationship was found between sex of owners and the forest practices included in this study. However, female owners were more interested in leasing and rated the importance of increasing the productivity of forest lands higher than male owners.

Rural or Urban Background.—Owners with urban backgrounds rated forestry higher and were practicing more forest management than owners with rural backgrounds.

Owners who had lived most of their lives in an urban environment were more interested in tree planting and in entering a long-term lease than were owners who had lived most of their lives in a rural environment. Urban owners were more willing for the public to use their lands for recreational purposes. Owners with a rural background were combining timber growing and grazing more often than those from an urban area.

Present Residence.—Nearly half of the owners lived on some part of their property and present residence had a highly significant relationship with plans for forest lands, constructing fire lines, fencing, prescribed burning, and interest in leasing their forest land. Plans for planting trees and main use of forest land were significantly associated with residence. Resident owners were more interested in constructing fire lines, prescribed burning, fencing, and grazing, while absentee owners indicated more interest in leasing, planting trees, and recreation. Absentee owners placed a higher priority on increasing the productivity of forest lands and were doing more forest management than were resident owners. Absentee ownership was found to be compatible with forest management.

Children in School.—The presence of school-age children in the home had a highly significant association with the owner's personal feelings concerning the need for increasing the productivity of forest lands, and had a significant association with prescribed burning, interest in obtaining forest credit, plans for fencing, and plans for constructing fire lines. A higher percentage of the owners with children in school showed interest in the above activities than did owners without children in school.

Owners of Pine and Hardwood Forests.—There were many differences between owners of pine forests and hardwood forests in land use. The production of wood was the main use listed by 56 percent of the owners (187 of 336) on a statewide basis and was the leading use in both the pine and hardwood areas. However, 79 percent of the owners of pine forests were using their forests primarily for wood production, compared with only 32 percent of the owners of hardwood forests.

Grazing was the main use of forest land reported by 60 owners (18 percent) and wildlife management by 53 (16 percent). Owners of hardwood forests listed grazing as the main use of their land twice as often and wildlife five times as often as did owners of pine forests. However, the forage, wildlife, and other timber resources were not being managed. Recreation was the main use listed by 15 owners, with 12 of them being in the hardwood area. More hardwood owners had plans to remove forests from the land and they were less willing for the public to use their lands for recreational purposes than owners of pine forests.

Owners of pine forests were more active in forest management practices such as harvesting, removing cull trees, constructing fire lines, prescribed burning, and fencing, and they ranked the importance of increasing the productivity of their forest lands higher than did owners of hardwood forests. Also, almost twice as many pine owners had paid the entire cost of forest improvement practices. Owners of pine forests sold timber more frequently than owners of hardwood forest.

Land Use and Forest Management Practices.—Timber growing was cited as the main use of forest land by 56 percent, grazing by 18 percent, and wildlife by 16 percent of the owners. Twelve percent of the interviewees had plans to clear their timber land and use it for row crops or pasture.

Twenty-eight percent of the owners listing wood production as the primary use listed no secondary use for their forest lands, while 24, 20, 17, and 7 percent listed wildlife, timber growing, grazing, and recreation as secondary uses, respectively.

One hundred and twelve owners (34 percent) had been helped, on one or more occasions, in such activities as marking timber, insect control, plowing fire lines, conducting prescribed burns, and removing cull trees. Therefore, the combined efforts of all programs of landowner assistance from all sources (public and private) for nonindustrial owners had not reached two-thirds of the owners in the sample.

Seventy-nine percent of the interviewees said they would take advantage of free help in managing their timber, while 21 percent felt they had no need for forestry assistance. The latter group consisted primarily of owners planning to either clear forests from their lands or use their lands for some purpose that did not include the production of wood.

Only 17 landowners (5 percent) had a written management plan and only 46 owners (13 percent) had talked to a forester about a plan of management. The remainder (82 percent) felt they had no need for a written plan in handling their forest activities.

One hundred seventy-seven (53 percent) of the interviewees had timber cut from their forest land in the past decade, but only 13 owners did any of the harvesting. Fifty-nine percent of the owners had their timber cut for income or to thin their stands.

Forty-nine owners (27 percent of the sellers) had written contracts with buyers and most payments were on the basis of the cords or board feet harvested. Seventy-five percent of the 51 owners who put their timber up for bids received as many as three offers to buy. In making timber sales, 38 owners utilized some type of professional help from public, industry, and consulting sources.

Half of the interviewees planned to sell some timber in the next 10 years. Also, owners planned to use one or more additional forest practices, as follows: 149, thinning; 72, fencing; 63, prescribed burning; 55, timber stand improvement; 52, plow fire lines, and 41, planting trees.

Eighty-eight percent of the owners expressed the opinion that forest lands need to be more productive, but they also felt that anticipated returns to the owner from increased production would be insufficient to justify the financial investment required. Technical help, subsidies, and higher stumpage prices were suggested to make forestry more competitive with other uses for land and money.

Most owners (69 percent) permitted free use of their lands for recreational purposes, but half of them wanted the user to obtain permission in advance. An additional 5 percent of the owners permitted recreational use with the payment of a small fee. Young owners and absentee owners were more willing than older and resident owners for the public to use their lands for recreation.

Ninety percent of the owners made their own decisions regarding management practices, while 10 percent had delegated this responsibility to others. In general, owners of small tracts of timber have done little forest management. More than half of the owners planned to let unaided nature produce the goods and services, with the main function of the owners being to either store, harvest, or sell what is produced.

A fifth of the owners planned to do something to improve the productivity of their forests. The number of improved practices averaged 2.8 per owner.

Twenty-one percent of the interviewees did not list timber production as either a primary or secondary use of their forest lands. This included the 41 owners (12 percent) who planned to clear their land within 10 years and the 30 owners (9 percent) who had other plans for their forest lands.

No agricultural farming activities were being carried out on 61 percent of the ownerships. Seventy owners were active farmers, and 61 additional owners either rented or leased their agricultural land to someone else. Farming or rental payments for farm land was the main source of income for 86 (26 percent) of the respondents.

Ninety percent of the 131 ownerships where farming was an activity had received agricultural conservation program payments for farm practices in the past 10 years, compared with only 9 percent of the 336 owners in the sample who had obtained such payments for improving forestry practices.

In general, the younger, better educated, absentee, and higher income owners were the best forest managers. Many of the owners were in business, professional, self-employed, and wage-earner occupational groupings, lived away from the woodlot, had children in school, and belonged to community organizations.

Conclusions

Loss of forests through land clearing will continue for land uses that yield a higher rate of return to the owner than that received from forestry. Most of the loss will be in the Delta hardwoods.

Nonindustrial owners of the size included in this study, and those with more than 500 acres, hold the key to increased forest production in Louisiana. The forest growing stock on these holdings is insufficient to meet predicted future demands for forest resources.

Owners with certain characteristics are better candidates for increasing production of forests than others. Innovative owners with larger holdings who are professionals, self-employed, or wage earners will provide the greatest output per unit of external input. Also, more owners of pine forests will participate in intensive management programs than will owners of hardwood forests.

Major hazards to investment in timber growing include capital requirements, long periods of production, low rates of return to the landowner, taxes, fire, diseases, weather, insects, and other animals.

Harvesting (including marketing and regeneration), timber stand improvement, site preparation, and tree planting are the areas of forestry in greatest need of improvement. Harvesting is a critical time in determining the future productivity of forest lands. It presents an excellent opportunity to implement intensive forest practices on lands in a state of low productivity, as well as being a time that requires professional skills to maintain a high level of production on lands already under intensive management.

Federal programs for conservation practices have been more favorable to conventional farmers than to forest farmers.

The highest stumpage returns from intensive forest management are realized from longer rotations than those most suitable to nonindustrial owners.

Seventy owners in the sample and an estimated 23,387 owners in the state actually engaged in farming have an excellent opportunity to increase their income from forestry by partial harvesting of the forest products produced. They have the equipment needed to fell, buck, and skid forest products to a point for loading onto a truck. The work could be scheduled during times of the year when demands on their time from farming activities are at a minimum. The harvesting operation would increase the income from the forests and provide additional employment for the owners.

Owners of small tracts of timber have been doing about what other responsible citizens in Louisiana and the U.S. would do under similar circumstances. They have done a creditable job of providing goods and services under the prevailing institutional environment. Emphasis in the past has been concentrated on developing Louisiana and the U.S. by using natural resources. The result has been a gradual deterioration in the quality of timber stands to the point of low productivity.

A major investment is now required to convert forests on nonindustrial ownerships from a state of low production to high production. When this is accomplished, it is believed that a high level of production can be maintained with a satisfactory institutional environment and the application of forestry skills.

Almost all nonindustrial landowners recognize the need for increasing the productivity of forest lands. However, a satisfactory rate of return is not available to the forest landowner under current conditions. The economic, institutional, and technical factors associated with intensive forest management must be improved before any significant increase can be made in the productivity of forests on small nonindustrial ownerships.

Owners of small tracts of timber may already have made an adequate investment to represent their economic interest in productive forests, even though the rate of production is only about one-third of the potential. This investment is in the land itself, the timber currently on the land (even though it may be inadequate in both quantity and quality), and annual taxes. Also, most owners will pay part of the cost of improving their forests, but the remaining investment for increased production must come from some other source if forest improvement practices are to be an economically feasible operation for the landowner.

Some public programs have been developed for nonindustrial forest owners and these programs have improved forest practices. The most applicable federal programs for getting the job done (Cooperative Forest Management — 1950, and the Forest Incentives — 1973) are so small in size in relation to the job to be done that they are only scratching the surface of the problem. However, the incentives are in an amount and form that will help resolve the institutional, technical, and economic problems most responsible for the unproductive condition of forests on nonindustrial ownerships. Other programs in forestry will also be helpful in achieving and maintaining a higher level of production.

Private companies within the forest industry that have provided tree seedlings, advice, and, in some cases, entered into agreements to either manage or lease the forests on some nonindustrial ownerships have contributed to improved management. However, the programs are so small that these efforts fall in the category of desirable attempts to find the best methods for improving the industrial supply of wood.

The problem of achieving and maintaining more intensive forest management practices on nonindustrial ownerships is largely institutional, economic, and technical in nature.

The existing institutional environment for forestry provides the small nonindustrial forest owner with little or no income from the many intangible benefits produced and only about 5 percent of the tangible income resulting from intensive forest management. The remaining 95 percent of the benefits go to other segments of the economy and to the general public.

The general public has not provided an adequate forest management environment through the political institutions to represent its interest in achieving and maintaining high production on nonindustrial forest lands. One solution would be to improve the institutional environment for forestry to make it financially profitable for owners of nonindustrial forests to produce the goods and provide the services desired by the general public. Part of the justification would be that we are dealing with the most widely distributed, versatile, and renewable natural resource in Louisiana and the U.S. The tangible and intangible goods and services produced are many, and they are essential to our present and future environmental and economic health.

The most effective forest management programs involving financial assistance for owners of small timber tracts have been based on incentives. This has been a procedure used often in the U.S. in many fields to reach desired goals of programs. The primary objective of some of these programs related to forestry was something considered to be more important at the time than increasing forest production. However, more intensive forest management was one of several benefits resulting from these programs.

The main objective of Civilian Conservation Corps (1933) activities in forestry was to provide employment for young men. The primary purpose of the Tennessee Valley Authority reforestation program started in the 1930's was control of soil erosion. This was also the objective of the Yazoo-Little Tallahatchie Flood Control project started in northwest Mississippi in the 1940's. The main objective of the forestry provision of the Soil Bank Program (1956) was to reduce surpluses in agricultural crops. The forestry provisions of the above programs were effective in getting some forest practices accomplished by improving the institutional and economic factors that were preventing the action from taking place.

The most effective accomplishments in forestry to date have been achieved by programs that combined both financial and technical incentives. Financial assistance was necessary to make the practice economic for the landowner. Technical assistance, including professional forestry assistance and a forestry vendor service, was required to get effective performance. Based on the best information available, public participation is justified up to approximately 95 percent of the initial cost of achieving high production on medium and higher quality sites.

The federal government has made similar commitments in many areas in the 200-year history of the U.S. Highly successful investments of this type have been and are being made in agriculture. Forestry offers an outstanding opportunity for similar development.

Investments required to increase production of goods and services on nonindustrial forest lands in Louisiana and the U.S. would be substantial, and would probably need to continue for at least 30 to 40 years. However, there would be a favorable cost-benefit ratio to the public on at least the medium and higher quality sites of cooperating landowners. Also, all needs could be met with existing agencies and most needs could be met through increased support of existing programs.

Recommendations

Based on results and interpretations derived from this study, and programs initiated during the period of the study to improve management on small forest holdings, the following recommendations are offered.

1. Federal land-use policies regarding forestry provisions on capital gains, depletion, and charging of certain forest costs against annual income should be improved. These policies have provided the essential institutional foundation that has supported the growth of industrial forestry since their enactment in 1944. Forest manufacturing plants average a low rate of return from growing trees with a higher rate of return from processing trees grown in their forests and those purchased from nonindustrial owners. The average of the two rates of return permit a reasonable yield on invested capital for those in forestry with a wood manufacturing plant. However, the low and deferred rate of return from growing trees has not provided a satisfactory yield on invested capital for owners of small tracts of timber without manufacturing facilities. This is the main reason that little progress has been made in forest management on small ownerships.

Everyone involved in forestry is in greater need of these policies today than in the past because of inflation and the increasing cost of money. High rates of interest for investment funds put the capital-intensive, long-range forestry business in a less competitive position to attract money, especially for forest management purposes.

A continuation of the above policies is essential for at least two reasons. First, it is necessary in order to have a satisfactory institutional climate for the forest products industry that purchases the wood from the nonindustrial owner. Otherwise, the industry cannot either maintain its current role or reach its potential as an important employer of workers, creator of economic activity, and producer of more than 5,000 consumer products. Second, it is part of the institutional foundation that must be broadened to create a satisfactory institutional environment for nonindustrial owners without manufacturing facilities. Extending current policies to permit regeneration costs to be treated as expense items would be helpful.

2. The federal Forest Incentives Program enacted in 1973 should be funded each year at 100 percent of the estimated demand for funds on the current basis for cost-sharing. This program has improved the institutional, economic, and technical environment for forestry to the point that the more progressive nonindustrial owners that qualify will intensify their forest management practices.

Some additional suggestions for improving the Forest Incentives Program are:

—Increase the number of acres of forest land an owner may possess and still participate in the program. There is a big gap between the current limit of 500 acres and the 5,000 acres classified by the U.S. Forest Service as a small ownership. Retaining the current program limitation of $2,500 for all cost sharing per owner per year and keeping the rate of assistance at 75 percent of the total cost would impose adequate ceilings on participation each year by an owner. Assistance would be limited to probably less than 30 acres a year for those owners converting forest lands in the greatest need of improvement from a state of low productivity to high productivity. Also, the current limit on acreage creates an inequity for nonindustrial forest owners whose entire holdings are in forests and who own more than 500 acres. Current regulations permit owners of more than 500 acres of total land area to participate in the Forest Incentives Program and other conservation programs when the acres in excess of 500 are in open pasture or row crops. However, the owner is restricted if he owns more than 500 acres and it is all in forests.

—Limit the program to the acres with medium and high productive capacity to provide the most favorable benefits to the public in relation to cost. A minimum capacity to produce 60 cubic feet of wood per acre per year is suggested.

—Set a minimum number of acres for improvement in order to participate. This would increase the efficiency of the program and maximize public benefits in relation to costs.

—Minimize uncertainties regarding the level of annual funding to enhance the implementation of practices under the program and improve efficiency and accomplishments.

3. The nonindustrial forests of Louisiana and the United States should be researched with the same intensity that experiment stations (federal, state, and private) have researched and are researching the various row crops, livestock, and horticultural crops. Improved techniques in forestry are needed at all levels of production and marketing, including costs and returns.

4. All forestry programs (federal, state, and private) in diseases,

education, fire, harvesting, insects, marketing, research, tree genetics, tree seedling production, taxation, and utilization should be reviewed to determine what is needed to make it economically feasible for nonindustrial forest landowners to produce the goods and services that are in the public interest.

5. A better source of both short- and long-term credit on standing timber should be established for nonindustrial owners as an alternative to timber liquidation when the owner has an urgent need for funds. The rate of interest should be low enough not to exceed the rate of increase in the value of stumpage.

6. Louisiana should consider enactment of a program similar to those established in Virginia (Virginia Reforestation Law, 1970), Mississippi (Forest Resources Development Act, 1974), and North Carolina. Each of these states has enacted legislation that provides specialized equipment and financial aid to nonindustrial timberland owners for such practices as timber stand improvement, site preparation, stand conversion, prescribed burning, and tree planting. Such programs, along with the federal Forest Incentives Program, should improve the institutional, economic, and technical environment for forestry to the point that the more progressive nonindustrial owners that qualify will start intensifying their forest management practices.

7. Total forestry efforts at all levels should be reviewed and coordinated to provide strong, coordinated leadership from local to national levels to generate and sustain the cooperative action needed to accomplish and maintain increased productivity on nonindustrial forests.

8. The forest products industry should be encouraged to increase its assistance to owners of small tracts of timber. Appropriate equipment to accomplish stand conversion and other cultural practices should be made available at cost. Competent vendor services should be expanded. Industry should become more involved in harvesting operations on nonindustrial holdings in an effort to maximize income to landowners, to improve the future productivity of forest lands not fully productive, and to maintain a high level of production on lands already productive. It is recommended that forest land be leased as a partial substitute for buying land. The industry also should combine its resources with those of public research agencies in seeking the most efficient way of utilizing low-quality forests on nonindustrial ownerships and converting these lands from low to high productivity.

9. Consulting foresters should increase their assistance to owners of small tracts of timber, including the establishment or expansion of vendor services in forestry for small ownerships.

10. All agencies should provide all possible assistance in fully develop-

ing, using, and perpetuating the forest resources of Louisiana.

11. All citizens should provide maximum support to the development of an institutional environment that will promote full development, use, and perpetuation of the forest resources of Louisiana.

12. Everyone involved in management and harvesting of timber crops should do everything they can to get forest improvement practices accomplished at the time of harvest, which will improve the future productivity of forest lands not fully productive, and to maintain a high level of production on lands already productive. Also, individual and group activities should be coordinated with total efforts from all sources.

13. The Office of Forestry, Louisiana Department of Natural Resources (formerly the Louisiana Forestry Commission), should increase its services in forest management on a fee basis in all parishes with fire protection up to the limit of compatibility with other programs. Additional vendor services should be either developed from private sources or provided by the commission in all areas where the total supply from all sources is inadequate.

Literature Cited

Anderson, Walter C. 1960. The small forest landowner and his woodland. U. S. Forest Serv., Southeast. Forest Exp. Sta. Paper 114, 15 p., illus.

———. 1968. Factors influencing North Carolina landowners to practice forestry. Southern Forest Exp. Sta., U.S. Forest Res. Paper SO-33. 18 p.

———. 1975. Timber stand improvement — an entree to forestry for small-tract owners. Jour. Forestry 73:222-223.

Barrett, Leonard I. 1962. Special problems of the small forest owner in the U.S., Fifth World Forestry Cong. Proc. 1960: 1137-1148.

Bethune, James E. and W. P. LaGrande. 1960. Profitable small forest management — A case history. Forest Farmer 20 (1):12-13, 38.

Bradford, Lester E. and C. B. Marlin. 1972. Knowledge of forestry concepts compared with adoption of forest practices in two Louisiana parishes. La. State Univ., Forestry Notes 98. 4 p.

Chamberlain, H. H., L. A. Sample, and Ralph W. Hayes. 1945. Private forest land ownership and management in the loblolly-shortleaf type in Southern Arkansas, Northern Louisiana, and Central Mississippi. La. Agr. Exp. Sta. Bull. 393.

Chambers, Robert G. 1976. Third forest notebook. Forests and People 26(3):26-30.

Coutu, A. J. 1960. Is forestry financially practical for the small timberland owner? Forest Farmer 20(1):8-10, 32-33, 35.

———. 1961. Role of the small landowner in the changing pattern of southern forestry. Forestry. Forest Farmer 20(11):6-7.

Craig, D. A. 1972. How an incentives program would operate. Forest Farmer 32(2):20-21, 26-27.

Duerr, William A. 1960. Fundamentals of forestry economics. McGraw-Hill, Inc., N. Y.

Folweiller, A. D. 1944. Forest land ownership in Louisiana and its influence on timber production. La. Agr. Exp. Sta. Bull. 377.

——— and H. J. Vaux. 1944. Private forest land ownership and management in the loblolly-shortleaf type of Louisiana. Jour. Forestry 42:783-790.

Fontenot, R. W. and C. B. Marlin. 1974. Characteristics of owners of small timber tracts in Southwest Louisiana. La. State Univ. Forestry Notes 106. 4 p.

Gould, Ernest M., Jr. 1975. The search for parity. Jour. Forestry 73:217-221.

Gunter, Erin R. 1975. Forest landownership in Louisiana. La. Forestry Comm. 80 p.

Hair, Dwight. 1963. The economic importance of timber in the United States. U. S. Dept. of Agric., U.S. Forest Serv., Misc. Pub. 941.

Hestbeck, Fred M. 1963. A comparison of innovators to non-innovators among Louisiana pine woodland owners concerning the adoption of certain forest management practices by size of woodland. M.F. thesis, La. State Univ., Baton Rouge.

House Concurrent Resolution No. 101. 1970. Louisiana Legislative Calendar, 33rd Regular Session. p.475-476.

James, L. M., William P. Hoffman, and Monty A. Payne. 1951. Private forest land ownership and management in Central Mississippi. Miss. Agr. Exp. Sta. Tech. Bull. 35. 38 p., illus.

Jones, J. H., Jr., and A. S. McKean. 1962. A study of woodland management practices among small woodland owners in Louisiana. La. Agr. Ext. Serv. 8 p., mimeogr.

LeVasseur, Felix O. 1963. A comparison of innovators to non-innovators among pine woodland owners concerning the adoption of certain forest management practices by occupation of owner. M. F. thesis, La. State Univ., Baton Rouge.

Marlin, Clifton B. 1968. How should the cost of fire protection be shared? La. Agr. Exp. Sta. Bull. 625, p. 13-16.

Martel, John E. and Edmond B. Burns. 1976. Wood using industries of Louisiana. La. Forestry Commission Bull. 6, 9th ed. 38 p.

Martin, I. R. and Robert W. McDermid. 1960. Some viewpoints and characteristics of owners of small unmanaged woodlands. LSU Forestry Notes 42.

McArdle, R. E. 1956. Key to America's future timber supply. Proc. Am. Forestry Association, p. 161-162.

McClay, T. A. 1961. Similarities among owners of small forest properties in nine eastern localities. Jour. Forestry 59(2):88-92.

McDermid, R. W., Paul D. Kitt, and Sam Guttenberg. 1959. Ownership factors affecting management of small woodlands in St. Helena Parish, Louisiana. La. Agr. Exp. Sta. Bull. 520. 20 p.

McKillop, William. 1975. Social benefits of forestry incentive programs. Jour. Forestry 73:214-216.

McKnight, J. S. 1973. The forest service role in attaining third forest goals. Proc. 22nd Annu. L.S.U. Forestry Symp., La. State Univ., Div. Contin. Educ., Baton Rouge, p. 107-108.

Mignery, A. L. 1956. Factors affecting small-woodland management in Nacogdoches County, Texas. Jour. Forestry 54:102-105.

Mills, Thomas J. 1975. Investment priorities for small-owner assistance programs. Jour. Forestry 73:210-213.

——— and Daria Cain. 1976. 1974 Forestry Incentives program: indicators of cost-effectiveness. Jour. Forestry. 74:678-683.

Montgomery, Albert A., Vernon L. Robinson, and James D. Strange. 1975. Computer model offers guide for private woodland owners. Forest Farmer 34(8)6-7, 14-15.

Myers, J. Walter, Jr. 1973. Problems, opportunities and responsibilities of nonindustrial forest landowners. Proc. 22nd Annu. L.S.U. Forestry Symp., La. State Univ., Div. of Contin. Educ., Baton Rouge. p. 21-22.

Perry, J. D. and S. Guttenberg. 1959. Southwest Arkansas small woodland owners. U. S. Forest Serv., South. Forest Exp. Sta., Occas. Paper 170, 14 p., illus.

Pleasonton, A. and S. Guttenberg. 1961. Stimulating woodland management in North Mississippi: an appraisal. U. S. Forest Serv., South. Forest Exp. Sta. Occas. Paper 185. 15 p.

Pomeroy, Kenneth B. and James G. Yoho. 1964. North Carolina lands: ownership, use, management of forest and related lands. Am. Forestry Assoc., Washington. 372 p.

Porterfield, R. L. 1975. Sawlogs or soybeans. Forest Farmer. 35(10):16-17, 20.

Ramke, Thomas F. 1960. TVA Management studies. Forest Farmer 20(1):16, 30-32.

Resources for the Future, Inc. 1958. Forest credit in the United States. —A survey of needs and facilities. p. 10-13.

Seigworth, Kenneth J. et al. 1956. Influence of woodland and owner characteristics on forest management. TVA Division of Forestry Relations Report 217-56.38 p.

Sizemore, William R. 1970. The myth of wood supply from small forest landowners. Proc. Ann. Auburn Forest Forum 9.

Skok, Richard A. and Hans M. Gregersen. 1975. Motivating private forestry — an overview. Jour. Forestry 73:202-205.

Smith, Donald W. 1972. What industry is doing to encourage tree planting in the South. Forest Farmer 32(2):18 p.

South, Donald R., Thomas Hansbrough, and Alvin L. Bertrand. 1965. Factors related to the adoption of woodland management practices. La. Agr. Exp. Sta. Bull. 603. 25 p. ✓

Somberg. S. I. 1969. Characteristics of the small forest landowner in Alabama. Auburn Agr. Exp. Sta. Circular 155. 15 p.

Stevens, Arnold Joseph. 1963. Forest practices of Vernon parish landowners by size of woodland comparing selected innovators to non-innovators. Unpubl. thesis, La. State Univ. Library. 129 p.

Stoddard, Charles H. 1961. The small, private forest in the United States. Resources for the Future, Inc. Washington, D. C. 171 p.

Sutherland, Charles F., Jr. and Carl H. Tubbs. 1959. Influence of ownership on forestry in small woodlands. U.S. Forest Serv. Lake States Forest Exp. Sta. Paper, 77, 23 p.

Toms, R. E. and C. B. Marlin. 1972. Some characteristics of small landowners in the pine region of Northwest Louisiana. La. State Univ. Forestry Notes 100. 2 p.

Tucker, R. E. 1975. Monoculture in industrial southern forestry. Paper presented at 1975 Southern Forest Economics Workshop. 16 p., mimeo. ✓

Webster, H. H. and C. H. Stoltenberg. 1959. What ownership characteristics are useful in predicting response to forestry programs? Land Economics 35:292-295.

Worrell, Albert C. and Lloyd C. Irland. 1975. Alternative means of motivating investment in private forestry. Jour. Forestry 73:206-209.

Yoho, J. G. 1961. Have we a valid basis for defining the small forest owner problem? Supplement to "What's happening in forestry," 10 p. Washington.

———and J. Muench. 1962. What should we expect from our small private forests? Amer. Forests 68(1):26-27, 44, 46, 48.

APPENDIX

STATE OF LOUISIANA

INTERVIEW WITH OWNERS OF SMALL WOODLANDS

Owner [ ] Parish [ ] Questionnaire
Ward [ ] Number------------[ ]

1. How many years have you lived on this place? Years [ ]

How many years have you owned forested land? Years [ ]

Now,__________ I would like some general information about your land.

2. What is the total acreage of land you own in Louisiana? Total acreage [ ]
How many acres are farm land and pasture? Land & pasture [ ]
How many acres are forested? Forested acres [ ]
How many acres have been cut in last 10 years? Acres cut------[ ]

3. What is the main use of your forest land?
What is a secondary use (Indicate with number 2)

	Plot 1	Plot 2	Plot 3
Grazing--------	[ ]	[ ]	[ ]
Wildlife-------	[ ]	[ ]	[ ]
Timber growing-	[ ]	[ ]	[ ]
Recreation-----	[ ]	[ ]	[ ]
Other----------	[ ]	[ ]	[ ]

4. Is your home located on any of your woodlands? Yes [ ]
No [ ]

a. How many miles is most of your woodland from your home? Miles [ ]

b. Who manages your forest? Self [ ]
Other [ ]

5. Is any of your land being farmed at this time? Yes [ ]
No [ ]

(If yes)
a. Are you farming the land yourself? Yes [ ]
No [ ]

b. What is the main cash crop? Crop [ ]

c. Has this farming required additional investment of $5,000 or more in past 3 years? Yes [ ]
No [ ]

I am going to ask some questions concerning forest management:

6. What plans do you have for your woodland in the next 10 years?

Plot 1 ______________________________

Plot 2 ______________________________

a. Is there a written plan for forest management?
Yes ☐
No ☐

(If no)
b. Have you ever talked with a forester about a forest management plan?
Yes ☐
No ☐

(If yes)
c. Why wasn't the plan made? ____________________

7. Have there been any trees planted on your land in the past ten years?
Yes ☐
No ☐

(If yes)
a. How many trees have been planted? Number of Trees ☐

b. Do you intend to continue planting trees?
Yes ☐
No ☐

(If no)
c. Why have you made this decision? ____________________

8. If you needed help in managing your forest, what organization or person would you turn to? ____________________

9. Which one or ones of the following are you familiar with? (Read list)

Ext. Service------------☐
L.F.C.------------------☐
S.C.S.------------------☐
A.S.C.S.----------------☐
Consulting Forester-----☐
Company Forester--------☐
Other-------------------☐
None--------------------☐

a. How did you first learn about these people? (For agencies mentioned)

Agency	Reason
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________

b. Have any of the agencies every helped you with your forest land?

Yes ☐
No ☐

(If yes)
In what ways were they helpful?

Agency	Ways
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________

c. If you were offered free help in managing your woodland and in selling your timber, would you accept it?

Yes ☐
No ☐

(If no)
Why wouldn't you accept free help?

____

d. Have you ever received assistance from a forester?

Yes ☐
No ☐

(If no)
Why have you not used technical assistance?

____

Now, __________, I would like to discuss more specific forest practices:

10. a. Do you have any plans in the future for using any of the following practices?

(Read List)	Yes	No
Planting	☐	☐
Thinning	☐	☐
Removing cull trees	☐	☐
Fire line construction	☐	☐
Fence around forest	☐	☐
Prescribed burning	☐	☐
Other __________		

b. If you had extra money to spend on forestry, which one of the following practices would you spend it on?

(Read List)	Yes	No
Planting	☐	☐
Thinning	☐	☐
Removing cull trees	☐	☐
Fire line construction	☐	☐
Fence around forest	☐	☐
Prescribed burning	☐	☐
Other __________		

11. Have you obtained an ACP payment for any farm practice?
Yes [ ]
No [ ]

Have you obtained an ACP payment for any forestry practice on your land?
Yes [ ]
No [ ]

(If yes)
a. How many acres were planted under ACP? Acres [ ]
b. How many acres had cull trees removed? Acres [ ]
c. How many acres were fenced for forestry purposes? Acres [ ]
d. How many miles of fire lanes were plowed? Miles [ ]
e. Were there any other payment practices?
(Specify)____

12. Have you made investments into your forest where you paid the entire costs?
Yes [ ]
No [ ]

(If yes)
a. How many additional acres were planted? Acres [ ]
b. From how many additional acres did you remove the cull trees? Acres [ ]
c. How many acres did you purchase solely for growing trees? Acres [ ]

13. Would you be interested in entering into a long-term lease agreement, 25 yrs. or more, with a pulp and paper company or sawmill?
Yes [ ]
No [ ]

(If no)
a. Why are you not interested?________________________________

14. Would you be interested in entering into a short-term lease arrangement, less than 25 yrs., with a pulp and paper company?
Yes [ ]
No [ ]

(If yes)
a. How many years would you be interested in?
Number of years [ ]

15. Do cattle graze on any of your forest land at anytime of the year?
Yes [ ]
No [ ]

16. Do you have fire lines around any of your woodland?
Yes [ ]
No [ ]

Now, __________ that we have discussed forest practices in general, I would like to ask some questions concerning timber harvesting on your land:

17. Have you sold any timber or forest products in past 10 years?
Yes [ ]
No [ ]

(If yes) (If no, to to M part)

a. How much of the following have you sold off your land?

(Read list)
Firewood (cords)---- [ ]
Fenceposts (number)- [ ]
Pulpwood (cords)---- [ ]
Sawlogs (MBF)------- [ ]
Other ____________

b. Why did you sell at this time?
Sale 1____________

Sale 2____________

Sale 3____________

c. Did you do any of the cutting or harvesting yourself?
Yes [ ]
No [ ]

d. Was your timber ever marked for sale? Yes [ ]
No [ ]

(If yes) Did you pay for the marking? Yes [ ]
No [ ]

e. Was there a writtern contract on any of the sales?
Yes [ ]
No [ ]

f. Did you receive payment in one lump sum or were you paid by the cord and board foot?

	Lump	Cd/bd. ft.
Sale 1	[ ]	[ ]
Sale 2	[ ]	[ ]
Sale 3	[ ]	[ ]

g. Did you ever receive more than one bid for any sale?
Yes [ ]
No [ ]

(If yes)
1. How many bids did you receive? Number [ ]

2. Why did you choose one buyer over another? ____________

h. What professional help or advice did you have in preparing for and making the sale? ____________________

Did you pay for this help?
Yes ☐
No ☐

i. Did you know the price of stumpage before you established contact with a buyer?

	Yes	No
Sale 1	☐	☐
Sale 2	☐	☐
Sale 3	☐	☐

j. Were you paid before cutting, during cutting, after cutting, or some kind of combination?

	Before	During	After	Combination
Sale 1	☐	☐	☐	☐
Sale 2	☐	☐	☐	☐
Sale 3	☐	☐	☐	☐

k. Did you ever know, before cutting, the total amount of money you would receive?
Yes ☐
No ☐

l. Were you satisfied with the sale?
Yes ☐
No ☐

What were your reasons for being satisfied (or unsatisfied)? ____________________

____

m. Why have you not made any sales? ____________________

n. Do you intend to sell any timber in the next 10 years?
Yes ☐
No ☐

(If yes)
How will you go about preparing for the sale and carrying it out? ____________________

____

Timber harvesting is only one use of the forest, I would like to get your view on some of the other aspects.

18. Which one of the following would best describe your feelings toward the public using your land for recreation? (Read list)

Using land without payment or permission [ ]
Using land with permission only--------- [ ]
Using land only with payment------------ [ ]
No use on the land for recreation------- [ ]

19. Do you feel you need and would use forest credit if it were readily available at a reasonable rate?
Yes [ ]
No [ ]

20. What would you say are the reasons many woodland owners do not use more forestry improvement practices than they do?___

____

21. What do you think is needed to get forest management practiced?

____

____

22. ___________I would like to get your feelings on the subject of how much responsibility the small forest owner has to the conservation of the land and forest. First, I want to know how productive you think our forest lands should be. Which one of the following do you agree with? (Read list)

Forest lands must be made productive-- [ ]
Forest lands should be made productive [ ]
Productivity is desirable but not important------------------------------ [ ]
Productivity is not desirable--------- [ ]

Second, I want to know how you feel toward your responsibility as a landowner to the idea of conservation and your obligation to society. You have a card with the choices. I want you to check the one that best fits your feelings.

Now, ________________ we need some information about you and your family.

23. Did you live on a farm or in a city most of your life?
Farm [ ]
City [ ]

24. How many community and civic organizations do you belong to?
Number [ ]

25. How many children do you have attending school? Number [ ]

26. (If head of household) How many people do you earn a living for?
Number [ ]

27. What is your occupation?________________________________

28. How many years of school did you have the opportunity to get? Highest grade attained [ ]

29. Did you get ownership by purchase, inheritance, gift, or another form?

	Purchase	Inheritance	Gift	Other
Plot 1	[ ]	[ ]	[ ]	[ ]
Plot 2	[ ]	[ ]	[ ]	[ ]
Plot 3	[ ]	[ ]	[ ]	[ ]

Is any of your land mortgaged?
Yes [ ]
No [ ]

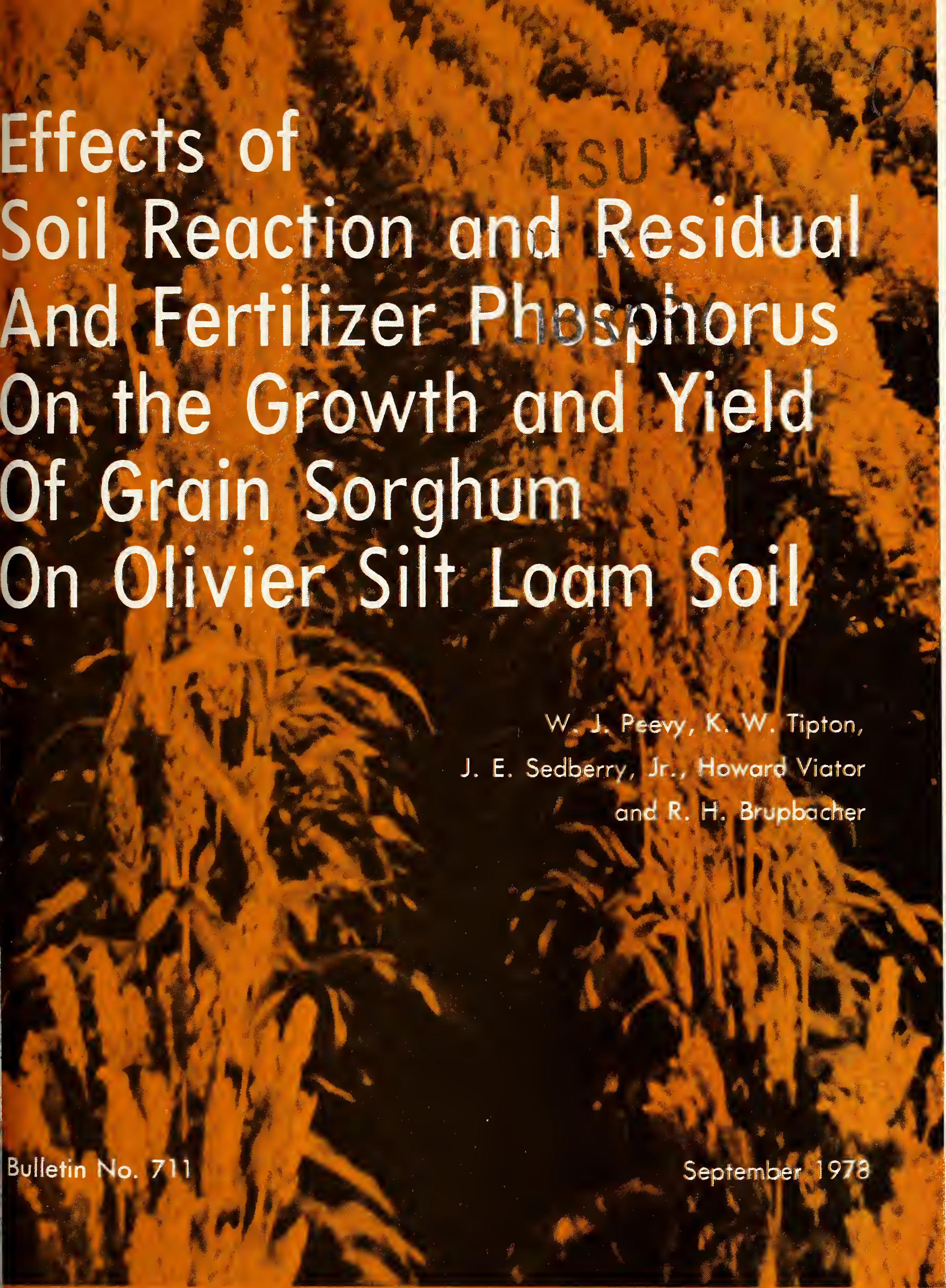
30. What was your age on your last birthday? Age [ ]

31. About how much was your income last year? Dollars [ ]

Sex
Male [ ]
Female [ ]

Race
Black [ ]
White [ ]
Mixed [ ]

Date____________________ Interviewer____________________



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Effects of Soil Reaction and Residual And Fertilizer Phosphorus On the Growth and Yield Of Grain Sorghum On Olivier Silt Loam Soil

W. J. Peevy, K. W. Tipton,
J. E. Sedberry, Jr., Howard Viator
and R. H. Brupbacher

Bulletin No. 711

September 1978

LOUISIANA STATE UNIVERSITY
AND AGRICULTURAL AND MECHANICAL COLLEGE
Center for Agricultural Sciences
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AGRICULTURAL EXPERIMENT STATION
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Acknowledgments

The authors express their appreciation to Mr. Ted R. Holmes, Specialist (Editor) and project leader, Division of Communications, LSU Cooperative Extension Service, for taking the photographs used in this publication.

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Effects of Soil Reaction and Residual and Fertilizer Phosphorus on the Growth and Yield Of Grain Sorghum on Olivier Silt Loam Soil

W. J. PEEVY, K. W. TIPTON, J. E. SEDBERRY, JR.,
HOWARD VIATOR AND R. H. BRUPBACHER[1]

Introduction

Interest in growing grain sorghum in Louisiana has increased in the past few years, although it is still a minor crop in the state. Very little soils research has been done to determine agronomic practices necessary for production of this crop on the soils of Louisiana.

During the past 35 years, many thousands of soil samples have been analyzed from the Loessial Hill and Mississippi Terrace soil areas of Louisiana. These analyses have shown that most of these soils contain relatively low amounts of extractable phosphorus, and most are moderately to strongly acid *(1, 3, 4)*.[2] Many farmers who grow crops on these soils make poor yields because of the low fertility of the soils. On the other hand, some farmers have used large amounts of phosphate fertilizer and lime, and continue to do so without knowing whether the practice is beneficial.

Many studies have shown that the phosphorus content of soils is increased by the use of fertilizer phosphorus, and that this soil phosphorus supplies plant needs for many years. Studies at the Rothamsted Experiment Station in England, as reported by Russell *(6)*, showed that, after 60 years of cropping, barley plants were still removing about 10 pounds of P_2O_5 per acre (4.5 kg/ha) annually from the phosphorus applied many years earlier. This is about one-half of the barley plant's requirement for phosphorus to produce 40 bushels (14 hl). In Alabama, work by Ensminger *(2)* showed that residual phosphorus was producing large increases in yields of cotton 20 years after any fertilizer phosphorus had been applied. Research by Peevy, et al. *(5)* with soybeans on Olivier silt loam soil at the Perkins Road Farm, Baton Rouge, showed that residual soil phosphorus was very effective in the production of that crop, and especially when the soil pH was above 6.5.

---

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[2] Italic numbers in parentheses refer to Literature Cited, page 16.

Experimental Area and Procedure

An experiment was initiated in 1973 to determine the effects of soil reaction (pH), residual soil phosphorus, and fertilizer phosphorus on the growth and yield of grain sorghum grown on Olivier silt loam soil at the Perkins Road Farm, Baton Rouge. The Olivier soil occurs in the Loessial Hill and Mississippi Terrace areas of Louisiana, and is fairly similar to other soil series in these areas. These soil areas are shown in Figure 1.

The area used in this work had been in a cotton-corn rotation for 18 years prior to 1967. The area consisted of limed and unlimed blocks of about 1.5 acres (.61 ha) each. Different phosphate treatments had left a fairly wide range of extractable phosphorus in the soil.

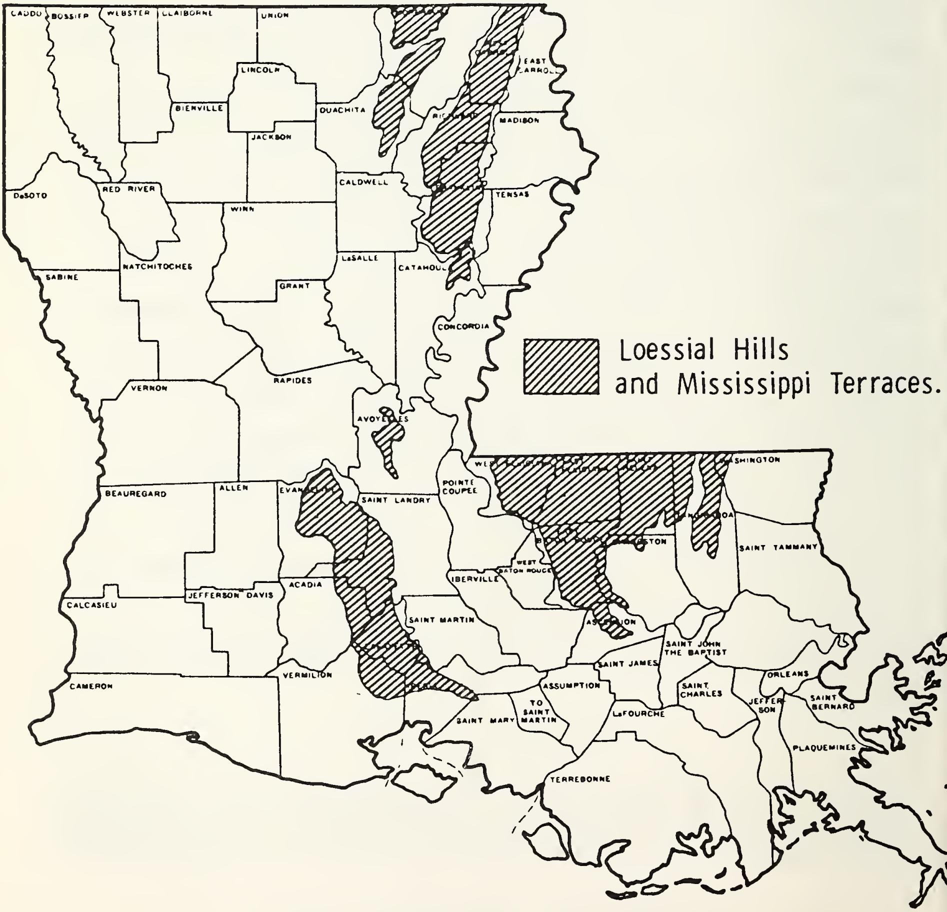

Figure 1.—Location of Loessial Hills and Mississippi Terraces in Louisiana.

In 1967 the area was divided into four blocks. Three of the blocks were limed to establish pH levels of about 4.8, 5.5, 6.2, and 6.6, respectively. In addition, a split-plot application of 60 pounds of P_2O_5 per acre (67 kg/ha) on each plot was used to study the effects of residual and fertilizer phosphorus, as well as pH, on yields of soybeans and cotton.

The work with grain sorghum, which was begun in 1973, utilized the same four blocks with the same pH values, and also continued the same split-plot phosphate applications that were used with soybeans and cotton. Potassium was applied as potassium chloride at rates of 60 to 70 pounds of K_2O per acre (67 to 78 kg/ha) annually. Nitrogen was applied at rates of 100 to 130 pounds per acre (112 to 146 kg/ha) from either ammonium nitrate or urea. The sorghum variety grown was G-516BR.

Extractable phosphorus was determined by extracting the soil with a solution of 0.10 normal hydrochloric acid containing 0.03 normal ammonium floride. A soil-to-water ratio of 1:20 and an extracting period of 15 minutes were used.

Soil reaction (pH) was determined with a pH meter. A slurry of soil and distilled water was used at a soil-to-water ratio of approximately 1:1.

Results and Discussion

All data presented are average yields for 3 years of the experiment—1973, 1974, and 1976. Excessive rainfall in 1975 caused damage to some plots and no yield data were taken that year.

Effects of Soil pH and Phosphorus on Early Growth of Grain Sorghum

Adjusting the soil pH from about 4.8 to 6.2 had a considerable effect on the early growth of grain sorghum, as shown in Figures 2 and 3. The average height at pH 4.8 was only about 6 inches (15 cm) when the plants were 5 weeks old. At pH 6.2, the plants were about 12 inches (30 cm) high at 5 weeks, and the plants were much heavier.

A comparison of pictures of the plants in Figures 2 and 4 shows the tremendous effect of adding fertilizer phosphorus at a very low soil pH. The soil phosphorus was also higher in plots represented by Figure 4, but the incidental placement of the fertilizer near the seed had a great effect on the growth of these plants soon after emergence. Much of this growth difference probably resulted from the addition of fertilizer phosphorus just before planting.

Even though the addition of fertilizer phosphorus at pH 4.8 gave a great increase in growth, the use of lime to raise the pH above 6 plus the use of phosphorus increased the average size of the plants by an additional one-third, as shown by comparing Figures 4 and 5. The plants shown in Figure 5 were about 24 inches (60 cm) high, and well developed, when they were only 5 weeks old. These four pictures illustrate the need for lime and phosphorus for the early growth of grain sorghum on this Olivier soil.

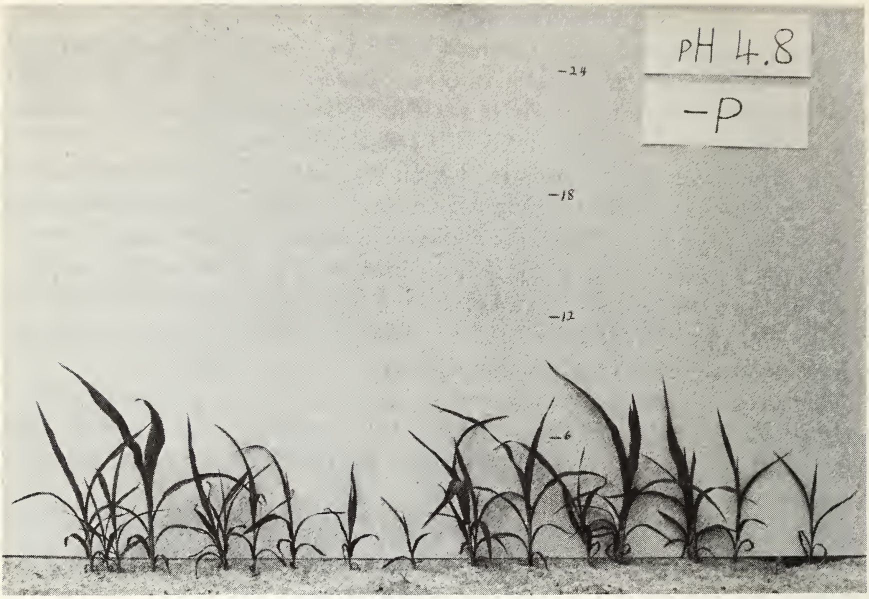

Figure 2.—Grain sorghum 5 weeks after emergence at pH 4.8, without phosphate fertilizer, on a low-phosphorus soil. Average height was about 6 inches (15 cm).

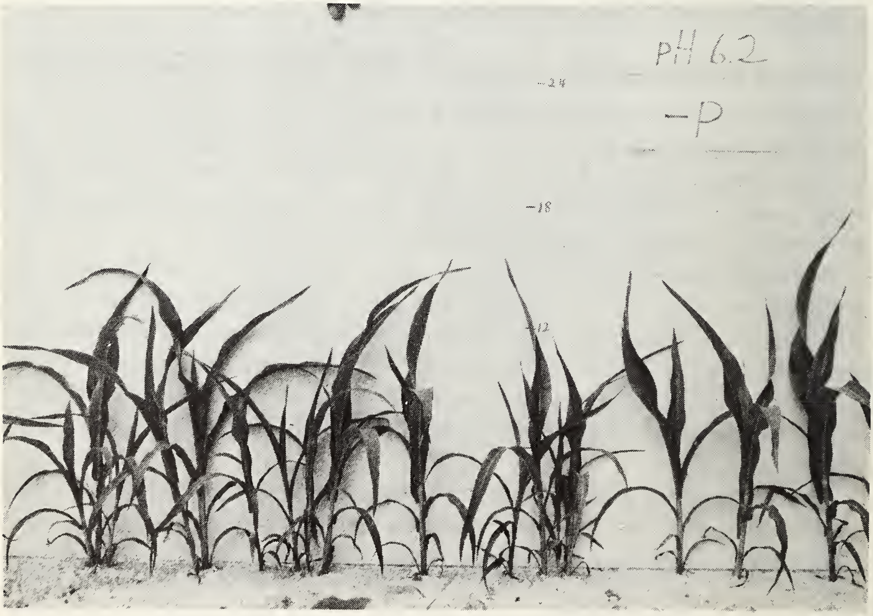

Figure 3.—Grain sorghum 5 weeks after emergence at pH 6.2, without phosphate fertilizer, on a low-phosphorus soil. Average height was about 12 inches (30 cm).

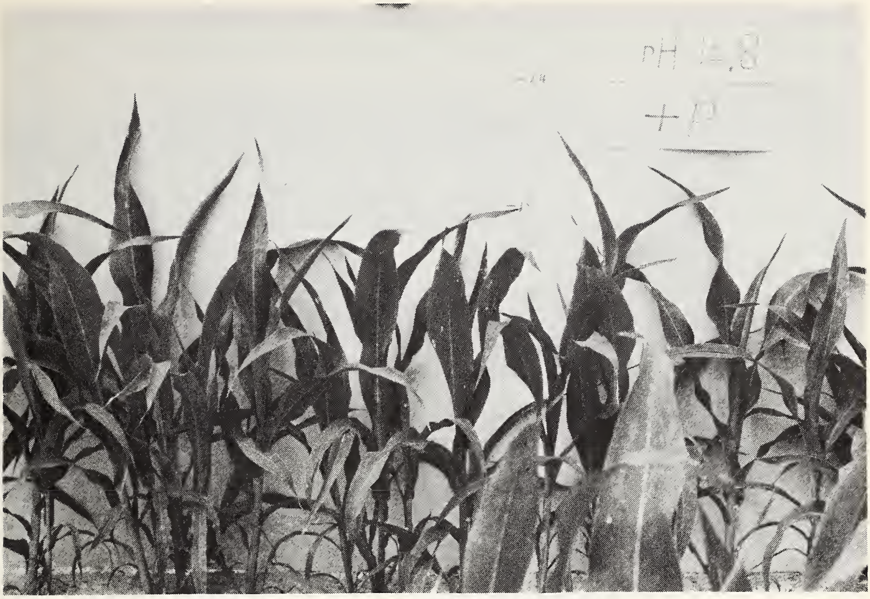

Figure 4.—Grain sorghum 5 weeks after emergence at pH 4.8 where fertilizer phosphorus was applied annually for 7 years. Average height was about 18 inches (45 cm).

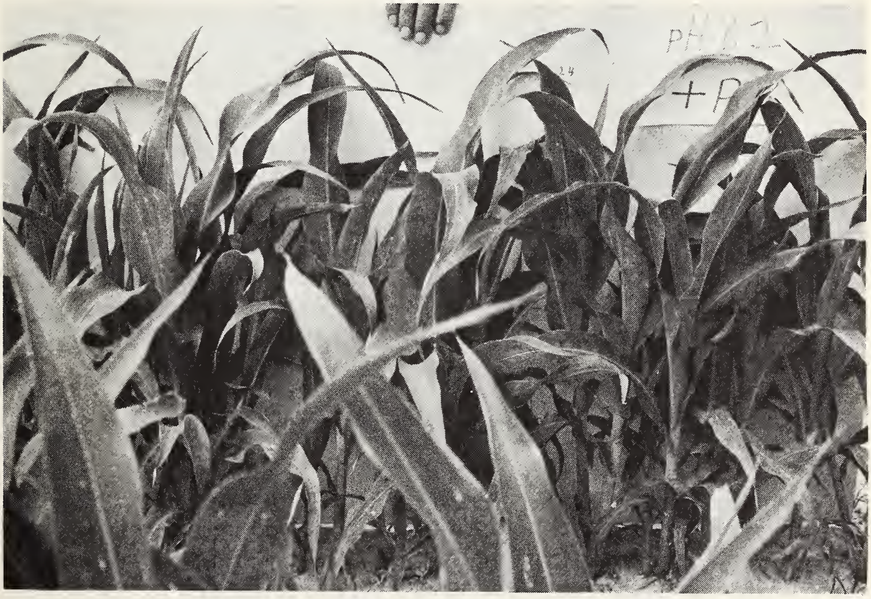

Figure 5.—Grain sorghum 5 weeks after emergence where the pH had been raised to 6.2 and where phosphate fertilizer had been applied for 7 years. Average height was about 24 inches (60 cm).

Effects of Soil pH and Phosphorus on Heading and Maturity Dates of Grain Sorghum

The heading dates of grain sorghum were much later on soils with low pH, and especially where no phosphate fertilizer was used, as shown in Table 1. The plots without phosphorus applications at pH 4.8 headed between July 11 and July 24, a span of 13 days. Where the pH was raised to about 6.6, all plots headed by July 7, whereas none had headed at pH 4.8 by this date. The range in heading dates was only 5 days at pH 6.6. The differences in heading dates at any pH were attributed to the variation in soil phosphorus. Plants in plots with high soil P headed earlier than those in plots with low soil P.

The addition of fertilizer phosphorus hastened heading dates at all pH levels. However, the difference at pH 6.6 between the phosphorus and no-phosphorus plots was very small.

Table 1.—Effects of soil pH and phosphorus on the dates of heading of grain sorghum, 1974

	Range in heading dates		Average heading date	
Soil pH	With P	Without P	With P	Without P
4.8	July 1-9	July 11-24	July 4	July 17
5.5	July 2-4	July 8-15	July 3	July 10
6.2	June 30-July 3	July 3-14	July 2	July 10
6.6	July 2-5	July 2-7	July 4	July 5

The effect of phosphorus on heading date at pH 4.8 is shown in Figure 6. The plot in the foreground had not received phosphate fertilizer for many years and none of the plants had headed. The plot in the background had received phosphate fertilizer for 7 years and plants were fully headed.

Maturity dates, as well as heading dates, were affected by soil pH and phosphorus. The plots with phosphate fertilizer and higher pH were mature and ready to be harvested 2 weeks or more before the low pH-low phosphate plots.

Effects of Heading and Maturity Dates on Bird Damage of Grain Sorghum

Bird damage was also affected by dates of maturity. On the early maturing plots, bird damage was about 5 to 10 percent. On plots that were 2 to 3 weeks later in maturing, bird damage was 70 to 80 percent. It was not determined why this occurred. There may not have been as many birds present when the first plots were heading. Or, the fact that only a few plots were very late in maturing may have caused the birds to concentrate on these plots. The damage by birds occurred primarily when the grain was in

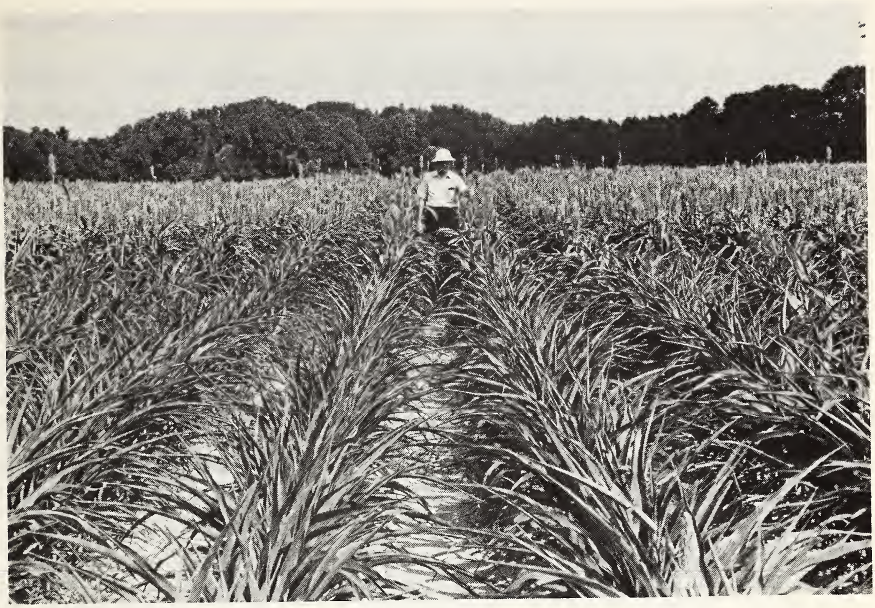

Figure 6.—Effect of fertilizer phosphorus on heading dates of grain sorghum with a soil pH of 4.8. Plot in foreground did not receive any phosphate fertilizer. Plot in background received phosphate fertilizer annually for 7 years.

the milk stage. Whatever the reason, the later and slower maturing plots were much more severely damaged.

Effects of Soil pH and Phosphorus on Yield of Grain Sorghum

Grain yield data at the four ascending pH levels are shown in Tables 2 through 5. Also shown are the amounts of extractable soil phosphorus present at the end of the experiment. Data are the averages of two replications for 3 years.

At a pH of about 4.8, the yields were very low, about 1,200 pounds per acre (1,344 kg/ha), where no phosphorus was used. The yields varied as the soil phosphorus levels varied, as shown in Table 2. The yields were so low that it would not be profitable to grow grain sorghum under these conditions. Where phosphorus had been applied annually since 1967 at pH 4.8, yields were much higher and averaged about 3,100 pounds per acre (3,472 kg/ha). There was little, if any, relationship between yield and soil phosphorus where fertilizer phosphorus had been added since 1967.

At pH 5.5 the yields without phosphorus were still very low, as shown in Table 3, but they averaged about 700 pounds per acre (784 kg/ha) higher than at pH 4.8, showing some benefit of lime even at the low phosphate level. Where phosphorus had been applied annually since 1967 at pH 5.5, the yields were about the same as at pH 4.8 where phosphorus had been applied.

When the pH was raised to about 6.2, the yields without fertilizer phosphorus were still relatively low, averaging about 2,500 pounds per acre (2,800 kg/ha), as shown in Table 4. However, they were double the yield at pH 4.8, and 30 percent higher than those at pH 5.5 where no phosphorus had been used.

When the pH was raised to 6.2 and phosphorus had been applied annually since 1967, yields averaged more than 4,000 pounds per acre (4,480 kg/ha), the highest of any treatment, showing the need for a well-limed soil, and phosphate fertilizer, for good yields on this soil.

When the pH was raised to about 6.6, the yields without phosphorus were higher than at pH 6.2 without phosphorus, as shown in Table 5. However, the soil phosphorus was also higher than at 6.2, and this probably helped to increase yield. There was no increase from the use of phosphorus at pH 6.6 over 6.2; in fact, yield tended to decrease at the high pH level with phosphorus fertilization.

Table 2.—Three-year mean grain yield of grain sorghum at soil pH 4.8

Fertilizer P used, 1967-77			No fertilizer P used, 1967-77				
Extractable P in soil, 1977	Yield		Extractable P in soil, 1977	Yield		Yield difference	
ppm	Lbs./A	Kg/Ha	ppm	Lbs./A	Kg/Ha	Lbs./A	Kg/Ha
38	3,303	3,699	20	2,012	2,253	1,291	1,446
52	3,252	3,642	21	1,676	1,877	1,576	1,765
45	3,169	3,549	19	1,651	1,849	1,518	1,700
30	3,335	3,735	13	746	836	2,589	2,900
27	2,932	3,284	12	792	887	2,140	2,397
30	2,705	3,030	11	539	604	2,166	2,426
31	3,005	3,366	13	506	567	2,499	2,799
41	2,898	3,246	18	1,265	1,417	1,633	1,829
35	3,470	3,886	19	1,964	2,200	1,506	1,687
Average:							
37	3,119	3,493	16	1,239	1,338	1,880	2,106

Table 3.—Three-year mean grain yield of grain sorghum at soil pH 5.5

Fertilizer P used, 1967-77			No fertilizer P used, 1967-77				
Extractable P in soil, 1977	Yield		Extractable P in soil, 1977	Yield		Yield difference	
ppm	Lbs./A	Kg/Ha	ppm	Lbs./A	Kg/Ha	Lbs./A	Kg/Ha
41	3,157	3,536	16	2,765	3,097	392	439
35	3,102	3,474	16	2,431	2,723	671	752
37	3,338	3,739	15	2,136	2,392	1,202	1,346
44	3,018	3,380	13	1,286	1,440	1,732	1,940
29	2,998	3,358	12	1,264	1,416	1,734	1,942
26	3,033	3,397	13	1,178	1,319	1,855	2,078
30	3,098	3,470	14	1,799	2,015	1,299	1,455
100	3,422	3,833	20	2,320	2,598	1,102	1,234
37	3,407	3,816	24	2,516	2,818	891	998
Average:							
42	3,175	3,556	16	1,966	2,202	1,209	1,354

Table 4.—Three-year mean grain yield of grain sorghum at soil pH 6.2

Fertilizer P used, 1967-77			No fertilizer P used, 1967-77				
Extractable P in soil, 1977	Yield		Extractable P in soil, 1977	Yield		Yield difference	
ppm	Lbs./A	Kg/Ha	ppm	Lbs./A	Kg/Ha	Lbs./A	Kg/Ha
41	4,132	4,628	17	3,111	3,484	1,021	1,144
38	4,242	4,751	13	3,370	3,774	872	977
56	4,304	4,820	13	3,290	3,685	1,014	1,136
34	3,958	4,433	10	1,511	1,692	2,447	2,741
34	3,732	4,180	10	1,762	1,973	1,970	2,206
25	4,051	4,537	9	1,686	1,888	2,365	2,649
22	3,880	4,346	13	2,004	2,244	1,876	2,101
26	4,072	4,561	14	2,862	3,205	1,210	1,355
37	4,032	4,516	14	3,179	3,560	853	955
Average:							
35	4,045	4,530	13	2,531	2,835	1,514	1,696

Table 5.—Three-year mean grain yield of grain sorghum at soil pH 6.6

Fertilizer P used, 1967-77			No fertilizer P used, 1967-77				
Extractable P in soil, 1977	Yield		Extractable P in soil, 1977	Yield		Yield difference	
ppm	Lbs./A	Kg/Ha	ppm	Lbs.A	Kg/Ha	Lbs./A	Kg/Ha
54	3,596	4,028	31	3,343	3,744	253	283
51	3,871	4,336	29	3,330	3,730	541	606
47	3,778	4,231	24	3,160	3,539	618	692
39	3,605	4,038	22	2,760	3,091	845	946
30	3,670	4,110	20	2,876	3,221	794	889
34	3,557	3,984	22	2,829	3,168	728	815
39	3,411	3,820	23	3,074	3,443	337	377
87	3,836	4,296	25	3,261	3,652	575	644
63	3,739	4,188	34	3,448	3,862	291	326
Average:							
49	3,674	4,115	26	3,142	3,519	565	633

The graphs in Figure 7 show that, on these strongly acid, low phosphate soils, the use of lime to raise the pH from 4.8 to 6.2 increased the yield from about 1,200 pounds to 2,500 pounds per acre (1,344 to 2,800 kg/ha). The use of phosphorus with no lime increased the yield from 1,200 pounds to 3,100 pounds per acre (1,344 to 3,472 kg/ha) at pH 4.8. The use of lime to raise the pH to 6.2 plus the use of phosphorus raised the yield to over 4,000 pounds per acre (4,480 kg/ha). Therefore, neither lime alone nor phosphorus alone gave the best yield. These data show the need for a relatively high pH and good phosphorus level for sorghum production on this soil.

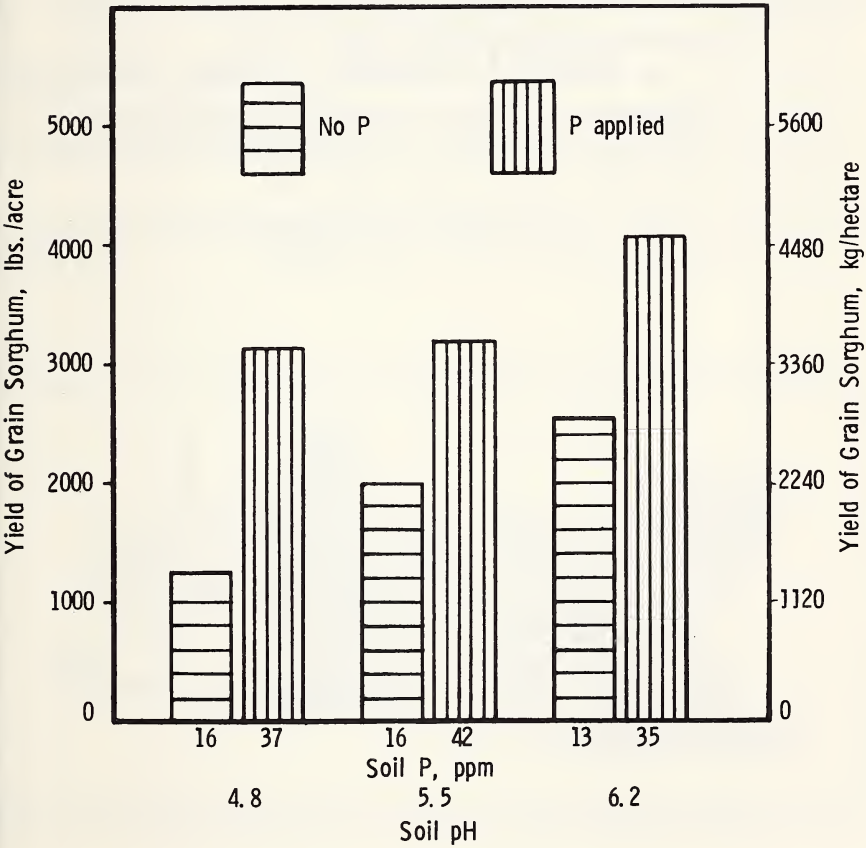

Figure 7.—Effects of soil pH and phosphorus on the yield of grain sorghum.

Literature Cited

1. Brupbacher, R. H., J. E. Sedberry, Jr., W. P. Bonner, W. J. Peevy and W. H. Willis. Fertility Levels and Lime Status of Soils in La. La. Agr. Exp. Sta. Bull. 644, 1970.
2. Ensminger, L. E. Residual Values of Phosphates. Alabama Agr. Exp. Sta. Bull. 322, 1970.
3. Peevy, W. J., and R. H. Brupbacher. Fertility Status of La. Soils. No. 1: Soil Reaction and Lime Needs. La. Agr. Vol. 5, No. 2, 1962.
4. Peevy, W. J., and R. H. Brupbacher. Fertility Status of La. Soils. No. 3: Phosphorus. La. Agr. Vol. 5, No. 4, 1962.
5. Peevy, W. J., B. E. Newman, J. E. Sedberry, Jr. and R. H. Brupbacher. The Influence of Soil Reaction, Residual Soil Phosphorus and Fertilizer Phosphorus on the Yield of Soybeans Grown on Olivier Silt Loam. La. Agr. Exp. Sta. Bull. No. 699, 1972.
6. Russell, E. Walter. Soil Conditions and Plant Growth. pp. 507-508, 1961. Longmans, Green and Co., Ltd. London.

Bulletin No. 712 November 1978

A Summary of NITROGEN STUDIES with FORAGE CROPS at the SOUTHEAST LOUISIANA DAIRY and PASTURE EXPERIMENT STATION

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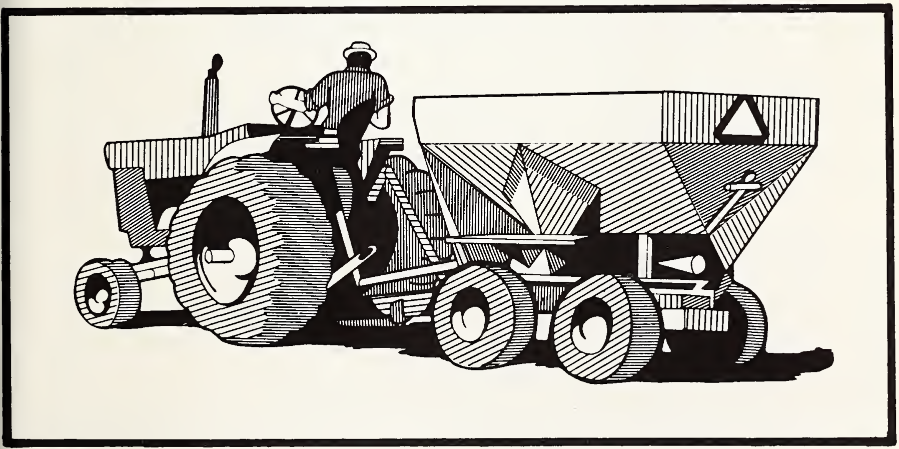

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A Summary of Nitrogen Studies with Forage Crops at the Southeast Louisiana Dairy and Pasture Experiment Station

MARVIN ALLEN, P. E. SCHILLING, H. D. ELLZEY,
AND O. D. CURTIS[1]

Introduction

Organized field plot research at the Southeast Louisiana Dairy and Pasture Experiment Station was initiated in 1951. The basic objective was to develop practices for the production of forage crops and their utilization by dairy animals.

The general soil area is characterized as gently sloping to hilly Coastal Plain. Predominate soil types are Lexington and Providence silt loam and, to a lesser extent, Bude silt loam, and Luverne and Ruston fine sandy loam.

The A-horizon of the topsoil ranges from 2 to 6 inches in depth. The native fertility status, as measured by extractable phosphorus, potassium, calcium, and magnesium, is considered very low.

One of the first agronomic objectives undertaken was to determine the role of applied nitrogen in grassland farming. There were many unanswered questions relative to the use of nitrogen. For example, to what extent would rates of nitrogen affect forage yield of various species? When should nitrogen be applied? Should nitrogen be applied in single or split applications over a growing season? Is one source of nitrogen superior to another?

The purpose of this publication is to summarize data obtained from experiments involving forage crops and applied nitrogen. Since several experiments are discussed, only brief and essential points with regard to the procedure of each experiment are made. Treatments of all experiments were replicated four times. Phosphorus and potassium is expressed in the oxide form, that is P_2O_5 and K_2O, respectively, as is commonly found on fertilizer tabs. The data included should provide a basis for the judicious use of nitrogen in forage production programs.

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Studies with Warm-Season Crops

Response of Millet Forage Yield to Nitrogen Rates and Applications

A 7-year study was conducted to evaluate the forage yield response of Pearl millet, *Pennisetum glaucum* L., to rates and numbers of applications of nitrogen (N). Starr variety was planted as the test crop the first 4 years, and Gahi-1 was planted the last 3 years. Plantings were made with a conventional grain drill at a seeding rate of 30 pounds per acre.

The experimental area was located on a Providence silt loam soil. Treatments were not repeated on the same plot sites over all years.

Phosphorus (P_2O_5) and potassium (K_2O) were applied uniformly at a rate of 140 pounds each per acre at planting.

Nitrogen rates were 0 to 480 pounds per acre, applied in 60-pound increments. Ammonium nitrate (33.5 percent N) was used as the source of N. The respective N rates were applied in single, two-, and four-way split applications. Nitrogen of single applications was applied at plantings. Half of the N of the two-way split was applied at planting and half after the second harvest. One-fourth of the N of the four-way split was applied at planting, and one-fourth was applied following the first, second, and third harvests.

Forage was harvested when the plants averaged 30 inches high. Forage was cut and removed at a stubble height of 6 inches.

The total number of treatments (25) was made up of eight N rates applied

Table 1.—Dry forage yield of millet averaged over all nitrogen rate-application combinations (25) by year[1]

Year	Forage lbs/a	No. of clippings
1956	13,410 f	4
1957	9,932 e	4
1958	7,336 d	5
1959	6,593 c	5
1960	4,604 a	3
1961	7,490 d	4
1963	5,253 b	4

[1] Means with same letter do not differ at the .05 level of significance.

in all possible combinations of single, two-, and four-way split applications, plus a no-N check. Season total yields averaged over all treatments by year are shown in Table 1.

Differences in environmental factors among years resulted in large yield differences. Most noticeable was a 291 percent higher yield in 1956 as compared with 1960. The number of clippings per season varied from three to five with four being typical. Data for 1962 were not included because of the effects of a drought.

Number of days from planting to first harvest usually ranged from 30 to 35. Generally, all clippings were made within a period of 60 to 90 days. Consequently, the average life span for millet varied from 90 to 120 days.

Over the 7-year study there was no statistically significant response of total dry forage yield per acre to number of N applications (Table 2).

Inspection of the data showed a lack of consistency in yield response to the number of applications of N among years. The variability in amount and distribution of rainfall among years was probably the main cause of the inconsistency. Within years total yield varied in response to the number of applications and N rates.

Mean yields of millet for N rates averaged over numbers of applications are shown in Table 3. There was a significant increase in total dry forage harvested with each added increment of N through 480 pounds per acre. The percentage yield increase per increment of N was highest at 60 pounds and least at 360 pounds and above.

The most efficient forage production occurred with 60 pounds of applied N. There was approximately a 1.5-pound decrease in forage produced per pound of N applied with each increment of N.

Assuming that all the forage produced would be properly utilized, the cost per pound of N and the value per pound of forage would indicate the rate of N economically justified to be used.

Table 2.—Mean yield response of millet to number of nitrogen (N) applications[1]

No. of N applications	Yield, lbs/a
1	8,140 a
2	8,065 a
4	8,043 a

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[1] Means with same letter do not differ at the .05 level of significance.

Table 3.—Mean yield responses of millet to applied nitrogen (N), 7-year average[1]

N, lbs/a	Yield lbs/a	% Yield increase per increment of N	Pounds forage per lb N
0	2,391 a	--	--
60	4,254 b	78	31.0
120	5,847 c	37	28.8
180	6,984 d	19	25.5
240	7,973 e	14	23.3
300	9,063 f	14	22.2
360	9,588 g	6	20.0
420	10,182 h	6	18.5
480	10,769 i	6	17.5

[1] Means with same letter do not differ at the .05 level of significance.

Response of Corn for Silage to Applied Nitrogen

A study was conducted to determine effects of applied nitrogen (N), plant population, and hybridization on the yield and quality of corn, *Zea mays* L., for silage. Results of this study have been reported in detail in Louisiana Agricultural Experiment Station Bulletin No. 676. Mean effects of applied N on yield are reported in Table 4.

Table 4.—Mean effects of applied nitrogen (N) on corn for silage*

N, lbs/a	Forage, tons/a Green	Forage, tons/a Dry	Grain, lbs/a	% Grain in forage[1]
100	19.9 a	6.7 a	4,628 a	34.7 a
200	21.3 b	7.3 b	5,108 b	34.9 a
300	21.3 b	7.2 b	5,031 b	34.8 a

Means with same letter in columns do not differ at the .05 level of significance.

[1] On dry matter basis.

Forage yield, on both a green and a dry basis, and grain yield were increased significantly by the application of 200 pounds of N as compared to 100 pounds. However, yields were not increased with an increase to 300 pounds of N per acre.

Grain content in the harvested forage was not affected by applied N, since N rates affected both forage yield and grain yield similarly.

Whether 200 pounds of N would be economically justified over 100 pounds would depend mainly on (1) the cost of N, (2) the value of forage, (3) the value of the grain, and (4) the availability of land.

Response of Forage Sorghum for Silage to Applied Nitrogen

A 5-year study was conducted to evaluate the response of a forage sorghum, *Sorghum vulgare* Pers., to rates of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O).

Plantings of Funk's 102-F variety were made in early May each year. A conventional grain drill was used to plant the seed in 7-inch drills at a rate of 25 pounds per acre.

N was applied at 100, 200, and 300 pounds per acre, and P_2O_5 and K_2O were applied at 50, 100, and 150 pounds per acre. Twenty-seven treatments, comprising all combinations of rates of application for the three nutrients, were used, and a no-fertilizer treatment was included as a check.

The sorghum was harvested when the grain in the upper half of the seedhead was in the hard dough stage of maturity. Harvest dates averaged about 95 days from planting. Dry matter content of the forage averaged about 32.5 percent.

Mean forage yield and percent of grain in response to each applied nutrient averaged over all rates of the other two nutrients are shown in Table 5. That is, yield shown at the 100-pound rate of applied N was the average yield of plots that received all three levels of P_2O_5 and K_2O and 100 pounds of N. Thus, each mean shown in Table 5 is an average of six treatments.

Most obvious were the increases in forage yield and grain content with the use of a complete fertilizer compared with the absence of applied fertilizer. Forage yield was almost doubled, and grain content increased about sixfold in response to fertilizer.

Increasing applied N from 100 to 200 pounds per acre resulted in a forage yield increase of 0.7 ton and a grain content increase of 3.6 percentage units.

Increases in yield in response to more than 50 pounds of P_2O_5 were relatively small and not of practical significance.

Yield increased with each increment of K_2O above the 50-pound rate. The application of 100 pounds of K_2O increased yield by 1.1 tons per acre over that of 50 pounds of K_2O.

It appears from these data that an application of 100 pounds of N, 50 pounds of P_2O_5, and 100 pounds of K_2O are adequate amounts of these plant nutrients to support near maximum crop yield.

Response of a Bahiagrass-White Clover Mixture to Rates and Numbers of Applications of Nitrogen

A 9-year study was conducted to evaluate the forage yield response of Pensacola bahiagrass, *Paspalum notatum* Flugge, to rates of applied nitrogen (N), and to the number of N applications.

An experimental area of bahiagrass sod was established on a Providence silt loam soil. Prior to establishment of the sod, 2½ tons of dolomitic limestone per acre were incorporated into the soil. Nitrogen treatments were repeated on the same plots of soil each year throughout the course of the study.

Eight N rates were applied in all combinations of one, two, and three applications, along with a no-N check for a total of 25 treatments.

Table 5.—Mean effects of applied nitrogen (N), phosphorus (P_2O_5), and potassium (
averaged over all possible combinations on the performance of a forage sorghum for si
5-year average*

Annual rates, lbs/a			Yield, green tons/a	% Gra in th forag
N	P_2O_5	K_2O		
0	0	0	9.9 a	2.9
100			17.1 bc	14.7
200			17.8 cd	18.3
300			17.8 cd	18.7
	50		17.4 bc	17.8
	100		17.6 cd	16.9
	150		17.7 cd	17.0
		50	16.7 b	16.8
		100	17.8 cd	18.1
		150	18.2 d	17.1

* Means with same letter do not differ at the .05 level of significance.

[1] Calculated on a dry matter basis.

Phosphorus (P_2O_5) and potassium (K_2O) were applied uniformly to all plots annually in early fall at a rate of 140 pounds each per acre. At the same time all plots were top-seeded annually to Louisiana S-1 white clover, *Trifolium repens* L., at a rate of 5 pounds per acre.

Plots were clipped to a 3-inch stubble when the forage height averaged approximately 10 inches. Harvest intervals were between 3 and 6 weeks throughout the season.

Each N rate was applied in a single, two-, and three-way split application. Single applications were applied in mid-March. Half of the N of the two-way split was applied in mid-March and half applied in late June. One-third of the N of the three-way split was applied in mid-March, one-third in late June, and one-third in early August.

Average total forage yield of the bahiagrass-white clover mixture by year, as an average of all 25 treatments, is shown in Table 6. Yield for most years was reasonably close to the overall mean of 11,485 pounds. Yield was exceptionally low in 1960, and exceptionally high in 1962.

As an average over all N rates, the number of applications had little effect on total dry forage per acre (Table 7). Yield response to applications was generally consistent among all N rates.

Although the number of N applications had no apparent effect on total forage produced, there was a pronounced effect on forage distribution

Table 6.—Dry forage yield of a bahiagrass-white clover mixture by year, averaged over all 25 nitrogen rate-application combinations[1]

Year	Yield, lbs/a
1957	9,559 b
1958	10,544 c
1959	12,361 e
1960	6,212 a
1961	13,717 f
1962	17,095 g
1963	11,785 d
1964	10,195 c
1965	11,911 de

[1] Means with same letter do not differ at the .05 level of significance.

Table 7.—Mean forage yield response of a bahiagrass-white clover mixture to nitrogen (N) applications[1]

No. of N applications	Yield, lbs/a
1	11,590 a
2	11,509 a
3	11,357 a

[1] Means with same letter do not differ at the .05 level of significance.

during the season (Figure 1). Single applications of N produced more forage in May and June than did the other applications. However, from early July until the end of the growing season growth obtained from the single application was lowest.

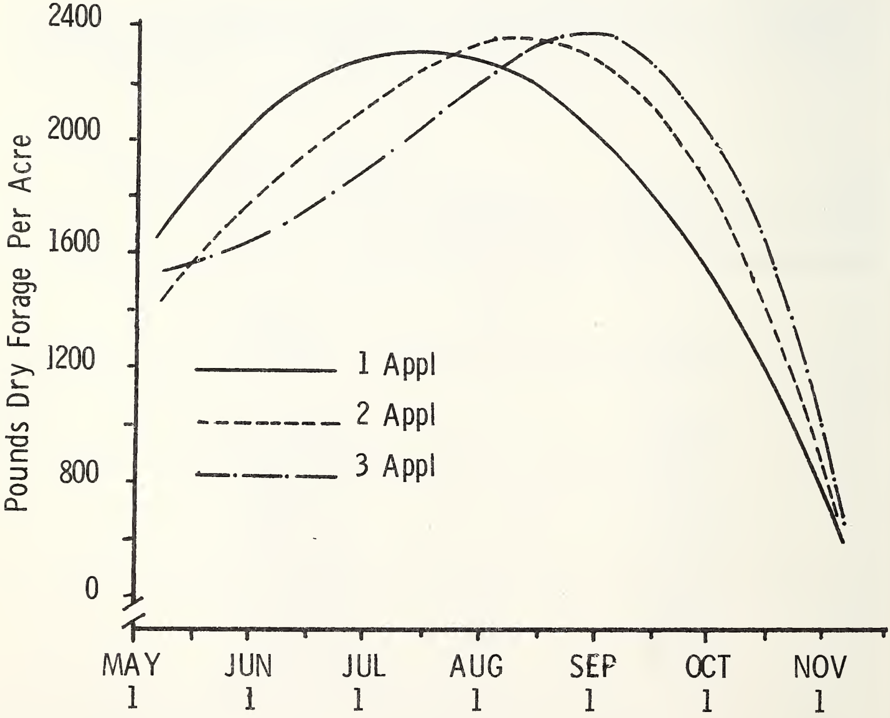

Figure 1.—Mean effect of application of N on seasonal yield of bahiagrass. Average of 5.4 clippings per year over 9 years.

Yield distribution with two applications of N was intermediate to that of one and three applications. Growth rate peaked in early July with a single application, early August with two, and early September with three applications.

Forage growth was lowest from May to August in response to N applied in three applications and was highest from September until the end of the season. Generally, as the number of applications increased from one to three, peak growth periods were delayed 1 month, respectively, from July to September. Yields at the end of the season were essentially the same, regardless of the distribution of the N applied.

There was a significant forage yield increase with each increment of applied N (Table 8). The greatest percentage increase was with 120 pounds of N. However, more forage was produced per pound of N with the application of 180 pounds.

These data indicate that yields were affected in part by the inclusion of clover. Clover accounted for a considerable amount of the forage produced at the 0 rate of N. The extent to which clover contributed to the forage mixture decreased as level of N was increased from 0 to 120 pounds. Clover did not persist on plots that received more than 120 pounds of N.

Rate of applied N had little effect on the distribution of growth throughout the season; it mainly affected the amount of growth (Figure 2). Forage

Table 8.—Mean yield response of a bahiagrass-white clover mixture to applied nitrogen (N), 9-year average[1]

N, lbs/a	Yield, lbs/a	% increase per increment of N	Lbs forage per lb N
0	5,887 a	--	--
60	7,086 b	20	20.0
120	8,780 c	24	24.1
180	10,425 d	19	25.2
240	11,806 e	13	24.7
300	12,810 f	9	23.1
360	13,192 g	3	20.3
420	13,578 h	3	18.3
480	14,208 i	5	17.3

[1] Means with same letter do not differ at the .05 level of significance.

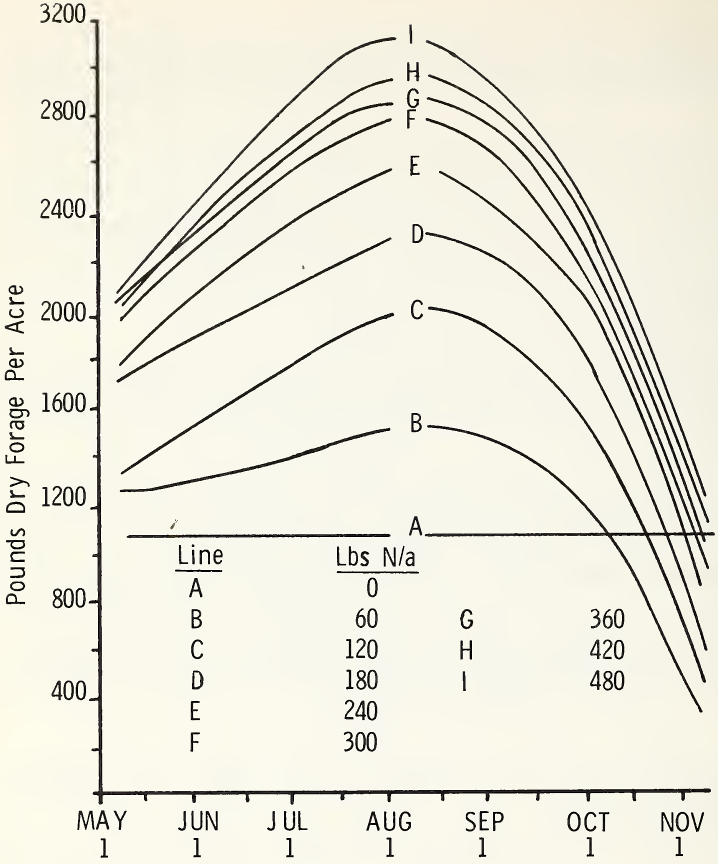

Figure 2.—Mean effect of N rates on seasonal yield of bahiagrass. Average of 5.4 clippings per year over 9 years.

produced in the absence of applied N was erratic among years, but as an average (Figure 2, line A), appeared to grow uniformly throughout the season.

None of the treatments resulted in the desired uniform distribution of growth that would alleviate management problems of excess or insufficient forage.

The Influence of Nitrogen Rate and Harvest Frequency on Forage Yield of Three Perennial Grasses

Forage yields of three warm-season perennial grasses were compared when harvested at different time intervals while using varying rates of applied nitrogen (N).

The grasses tested were dallisgrass, *Paspalum dilatatum* Poir; Pensacola bahiagrass, *Paspalum notatum* Flugge; and Coastal bermudagrass, *Cynodon dactylon* (L.) Pers. All grasses were overseeded annually in the fall with Louisiana S-1 white clover, *Trifolium repens* L.

Phosphorus (P_2O_5) and potassium (K_2O) were applied in the fall at a uniform rate of 140 pounds each per acre.

Yield means for harvest intervals, N rates, and grasses are shown in Table 9.

All N rates were applied in single, two-way, and three-way split applications. There were no differences in total yield due to the numbers of applications of N or N rates, or among grasses.

Generally, within N rates, yield was highest for bahiagrass, followed by bermudagrass and dallisgrass.

Table 9.—Effects of applied nitrogen (N) and harvest interval on dry forage yield of three perennial grasses[1]

Harvest interval, weeks	Season total yield			
	100 lbs N/a		200 lbs N/a	
	Dallis	Bahia	Dallis	Bahia
	- - Pounds per acre, 3-yr. avg., 1959-61 - - - -			
3	4,903 c	6,130 de	6,510 ef	9,197 g
5	5,846 d	7,001 f	7,051 f	9,929 h
7	5,216 c	6,545 ef	6,910 f	9,497 gh
5 (No N)	3,250 a	3,870 b		

Harvest interval, weeks	Season total yield			
	200 lbs N/a		400 lbs N/a	
	Coastal	Bahia	Coastal	Bahia
	- - - - - - - - - Pounds per acre - - - - - - -			
	5-yr. av., 1961-65		3-yr. av., 1963-65	
3	9,556 c	11,061 e	12,940 c	14,697 e
5	10,589 d	11,820 g	12,853 c	14,193 d
7	11,219 e	11,508 f	14,727 e	14,718 e
5 (No N)	5,198 a	5,711 b	4,325 a	5,865 b

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[1] Means with same letter in columns and rows within year average groups do not differ at the .05 level of significance.

Differential response of the grasses to environmental conditions among years probably accounted for the inconsistency that harvest interval had on yield. For the 1959-61 test years, yields were lowest at the 3-week interval of harvest and highest at the 5-week interval for both grasses at both N levels. In the 1961-65 test, Coastal yields were highest at the 7-week harvest interval and lowest at 3-week interval. Although yield differences were small among all harvest intervals, 5-week intervals resulted most often in highest yields.

In the 1963-65 test where 400 pounds of N was used, no real difference in Coastal yield was obtained between the 3- and 5-week intervals. However, Coastal yields at both of these harvest intervals were nearly 1 ton per acre lower than at the 7-week interval.

Relatively small yield differences were obtained due to harvest interval on bahiagrass receiving 400 pounds of N per acre.

These data reveal that on a Lexington silt loam Pensacola bahiagrass and Coastal bermudagrass are more responsive than dallisgrass to applied N. Any increase in yield obtained by extending harvest intervals beyond 5 weeks is probably not justified when effects of age on qualitative factors are taken into account.

Response of Bahiagrass to Applied Nitrogen and Potassium

A 5-year study was conducted to evaluate the response of Pensacola bahiagrass yield to varying rates of annually applied nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O). Results of this experiment were reported in Louisiana Experiment Station Bulletin No. 701.

Rates of applied N and K_2O and forage yields obtained are shown in Table 10. Dry forage yield was increased by about 1-ton per acre with an N rate of 300 pounds as compared to 200 pounds. An additional yield increase of about half a ton per acre was obtained when the N rate was increased to 400 pounds.

Yield response from applied K_2O appeared to be affected to a large extent by the rate of N applied. That is, as N rates were increased, higher rates of K_2O were required to support near-maximum growth. These data indicate that approximately 1 pound of K_2O is needed for each pound of applied N for greatest utilization of these nutrients, as expressed in yield.

Distribution of forage produced throughout the season, as affected by N rate, is illustrated in Figure 3. Generally, applied N, regardless of rate, had greater effect on total yield than on distribution of yield. Environmental factors throughout the season seemed to affect the distribution of forage growth. It appears from these data that proper utilization of forage throughout the season would require varying the stocking rate and/or harvesting excess forage as hay.

Table 10.—Mean effects of applied N and K_2O on the dry forage yield of Pensacola bahiagrass, 5-year average[1]

K_2O, lbs/a	N, lbs/a			
	200	300	400	Av
	Forage, lbs/a			
100	10,381 a	12,439 c	13,181 e	12,001 B
200	10,819 b	12,775 d	14,071 f	12,555 C
300	10,873 b	13,176 e	14,660 g	12,903 E
Av	10,691 A	12,797 D	13,970 F	

[1] Means with same letter do not differ at the .05 level of significance.

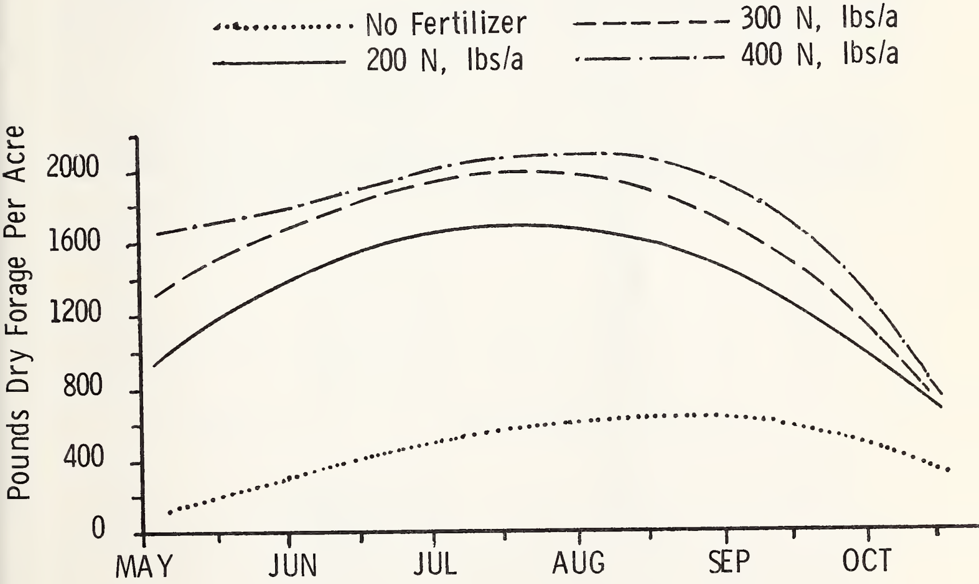


Figure 3.—Mean effect of applied N rates on seasonal yield of bahiagrass. Average of eight clippings per year over 5 years.

Influence of a Nitrification Inhibitor on the Forage Yield of Millet

A study was conducted to compare forage yield of Gahi-1 millet, *Pennisetum glaucum* L., in response to ammonium sulfate treated with varying levels of a nitrification inhibitor (Dow 163).

The treatment combinations and yield results are shown in Table 11.

Within the 60-pound rate of drilled N, yield was highest with the untreated ammonium sulfate. Yield decreased rather consistently as the inhibitor content was increased from 0.2 percent to 1.6 percent. This response was opposite to the effect expected.

Where N was applied broadcast yield was higher for the inhibitor-treated N than with the untreated ammonium sulfate. Yield was generally lower when 60 pounds of N was broadcast than when drilled.

At the 120-pound rate of N, there was a slight increase in yield with each increase in inhibitor content except at the 1.6 percent level.

Table 11.—Effects of ammonium sulfate (N) treated with a nitrification inhibitor (Dow 163) on the forage yield of millet

$(NH_4)_2\ SO_4$ Dow 163 treatment	Applied N, lbs/a	Method N applied	Yield, lbs/a
--	0	--	2,355
None	60	Drilled	6,863
0.2%	60	Drilled	6,551
0.3%	60	Drilled	6,341
0.4%	60	Drilled	6,188
1.6%	60	Drilled	6,105
None	60	Broadcast	5,543
0.4%	60	Broadcast	5,640
1.6%	60	Broadcast	6,045
None	120	Drilled	7,669
0.2%	120	Drilled	7,931
0.3%	120	Drilled	8,126
0.4%	120	Drilled	8,171
1.6%	120	Drilled	7,099
L.S.D. at .05 level of significance			906

Studies with Cool-Season Crops

Effects of Nitrogen Rate and Number of Applications on the Forage Yield of Oats

A 6-year study was conducted to evaluate the forage yield response of Moregrain oats, *Avena sativa* L., to rate and number of applications of applied nitrogen (N).

Phosphorus (P_2O_5) and potassium (K_2O) were applied annually at a rate of 140 pounds each per acre. A conventional grain drill was used to apply the fertilizer and plant the oats. The oats were planted in 7-inch drills at a rate of 128 pounds per acre. Plantings were generally made in late September.

Treatments were made up of eight rates of N applied in all possible combinations of single, two-way, and three-way split applications. A no-N treatment was included as a check.

Single applications of N were applied at planting. Half of the N of the two-way split was applied at planting and half in February. One-third of the N of the three-way split was applied at planting, one-third in late December, and one-third in early March. The oats were harvested to a 3-inch stubble when the forage averaged 10 inches high.

Average yields per growing season over all 25 treatments are shown in Table 12. Low yields in 1956-57 and in 1959-60 were attributed mainly to lack of moisture in the fall and unusually long periods of low temperatures during mid-winter.

Table 12.—Dry forage yield of oats averaged over all 25 nitrogen rate-application combinations

Season	Yield, lbs/a
1955-56	7,050 c
1956-57	4,363 a
1957-58	5,327 b
1958-59	7,890 d
1959-60	4,053 a
1960-61	7,256 c

[1] Means with same letter do not differ at the .05 level of significance.

Applications of N had a small but consistent effect on total yield (Table 13). As an average over all N rates, dry forage yield was increased by approximately 300 pounds per acre as the N applications were increased from one to three.

The number of applications had a greater effect on the distribution of the forage growth throughout the season than on total yield (Figure 4).

Averaged over all N rates, forage growth with single applications of N was greater during the first half of the season than in the remainder of the season. Growth response to the three-way split of applied N was lowest until late December and highest from mid-March until the end of the

Table 13.—Mean effect of nitrogen (N) application on dry forage yield of oats[1]

No. of N applications	Yield, lbs/a
1	5,671 a
2	5,968 b
3	6,238 c

[1] Means with same letter do not differ at the .05 level of significance.

Table 14.—Mean yield response of oats to applied nitrogen (N), 6-year average[1]

N, lbs/a	Yield, lbs/a	% Increase per increment of N	Lbs forage per lb N
0	1,690 a	--	--
60	3,307 b	96	26.9
120	4,481 c	35	23.3
180	5,498 d	23	21.2
240	6,140 e	12	18.5
300	6,676 f	9	16.6
360	6,989 g	5	14.7
420	7,242 h	4	13.2
480	7,341 i	1	11.8

[1] Means with same letter do not differ at the .05 level of significance.

season. Response of forage growth distribution to two-way split applications was intermediate to that of the single and three-way split applications.

There was an increase in dry forage yield with each 60-pound increment of N through 480 pounds per acre (Table 14). Total yield was doubled with the application of the first 60-pound increment of N compared with the zero level of N. However, 300 pounds of N was required to double the yield obtained with 60 pounds of N.

Apparently, 480 pounds of N was nearly the maximum that could be utilized because the percentage increase for the last N increment was only 1.0 percent.

Pounds of forage produced per pound of applied N decreased consistently as the N rate was increased. The most economical rate of N to apply would depend in part on (1) the cost of N, (2) the value of the forage, and (3) the yield needed to meet forage requirements.

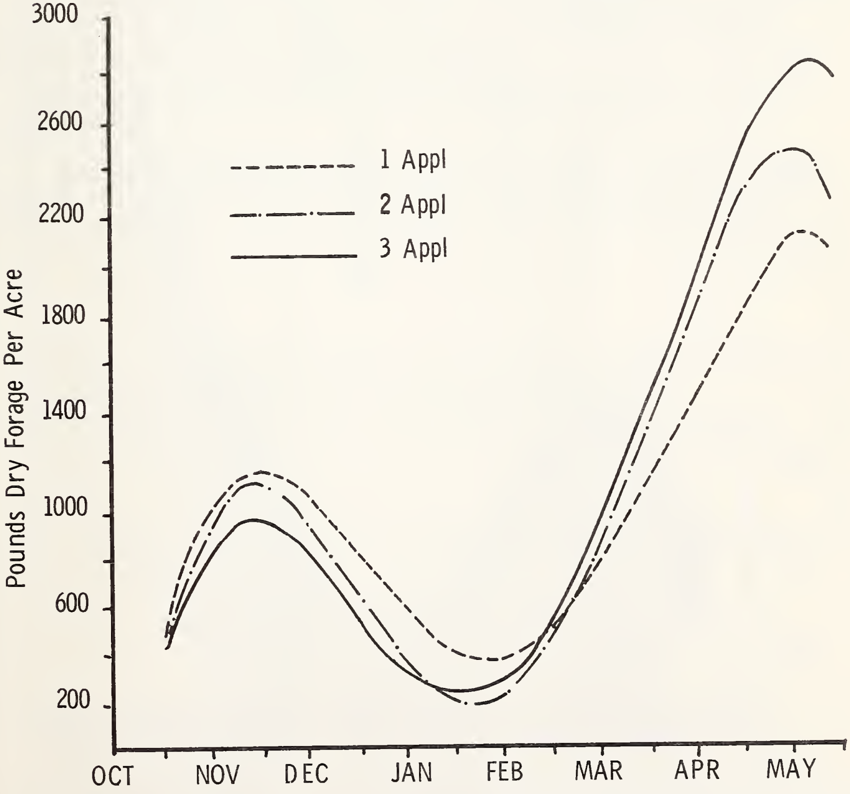


Figure 4.—Mean effect of N applications on seasonal yield of oat forage. Average of 5.5 clippings per year over 6 years.

Nitrogen rate had a lesser effect on distribution of forage growth throughout the season than on total yield (Figure 5). Yields were consistently higher thoughout the season with each increment of N. Growth was more rapid in October and November at the higher N rates than at the lower rates.

An initial flush growth occurred in early fall for all except the zero N level. Growth declined to its lowest rate in mid-January. The rapid growth throughout February, March, and April illustrates that acreage that provides sufficient forage during December and January also provides excess forage in the spring. Excess forage is generally harvested as a hay crop.

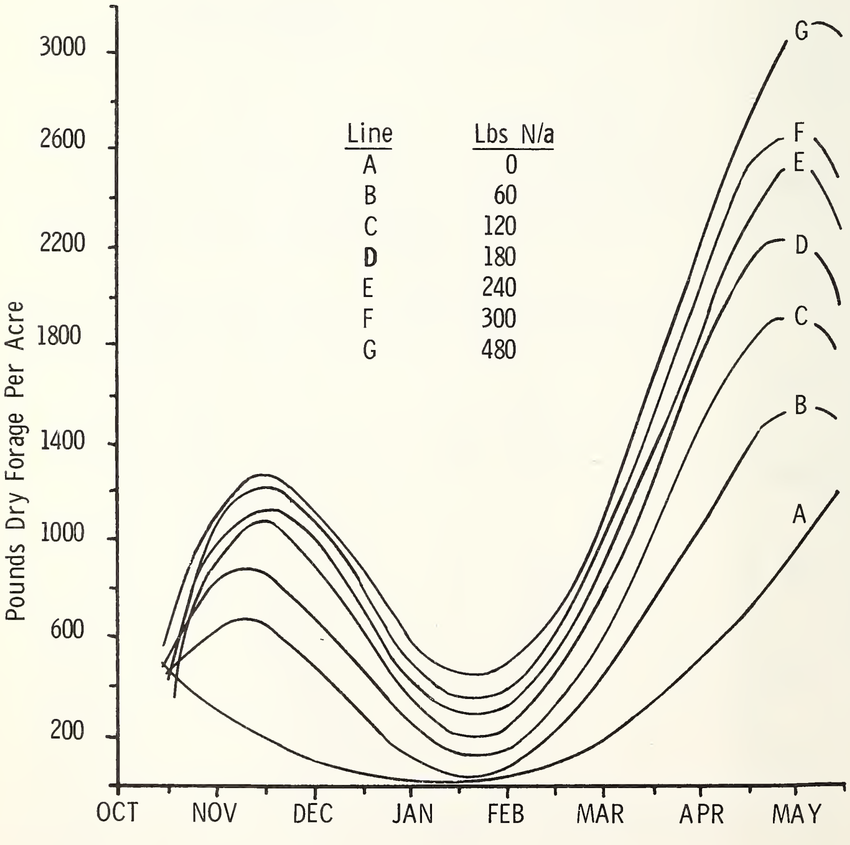


Figure 5.—Mean effect of N rates on seasonal yield of oat forage. Average of 5.5 clippings per year over 6 years.

Influence of Nitrogen Rate and Number of Applications on an Oat-Ryegrass-Clover Mixture

A 6-year study was conducted to evaluate forage yield response of an oat-ryegrass-clover mixture to rates and number of nitrogen (N) applications. Moregrain oats, *Avena sativa* L.; annual ryegrass, *Lolium multiflorium* (L.) Lam.; and common crimson clover, *Trifolium incarnatum* L., were used as the crop mixture.

The oats were planted at a rate of 112 pounds per acre in 7-inch drills. The ryegrass and clover were broadcast at 30 and 20 pounds per acre, respectively. Plantings were generally made in late September.

Phosphorus (P_2O_5) and potassium (K_2O) were applied annually at a rate of 140 pounds each per acre at planting.

Treatments consisted of eight rates of N applied in all combinations of single, two-way, and three-way split applications. A no-N treatment was included as a check.

Single applications of N were applied at planting. Half of the N of the two-way split was applied at planting and half in mid-February. One-third of the N of the three-way split was applied at planting, one-third in late December, and one-third in early March.

The crop was harvested to a 3-inch stubble when the forage averaged 10 inches high.

Total yields per growing season, averaged over all 25 treatment combinations, are shown in Table 15. Yields of this crop mixture were more consistent among years than were those of oats in a pure stand (Table 12),

Table 15.—Dry forage yield of an oat-ryegrass-clover mixture by season, averaged over all 25 nitrogen rate-application combinations[1]

Season	Yield, lbs/a
1955-56	7,472 b
1956-57	6,781 a
1957-58	8,724 d
1958-59	6,915 a
1959-60	6,968 a
1960-61	7,997 c

[1] Means with same letter do not differ at the .05 level of significance.

which reflects some of the advantages a crop mixture provides as compared to a single species. Generally, with a mixture one species will perform favorably under conditions that may be adverse to the other species.

The number of applications in which N was applied had a consistent effect on total yield (Table 16). Averaged over all N rates, as the number of applications increased from one to three, total yield increased rather linearly by about 800 pounds of forage per acre.

Table 16.—Mean effect of numbers of applications of nitrogen (N) on yield of an oat-ryegrass-clover mixture[1]

No. of N applications	Yield, lbs/a
1	7,034 a
2	7,355 b
3	7,839 c

[1] Means with same letter do not differ at the .05 level of significance.

Table 17.—Mean yield response of an oat-ryegrass-clover mixture to applied nitrogen (N), 6-year average[1]

N, lbs/a	Yield, lbs/a	% Increase per increment of N	Lbs forage per lb N
0	4,890 a	--	--
60	5,558 b	13.7	11.5
120	6,268 c	12.8	11.5
180	6,912 d	10.3	11.2
240	7,334 e	6.1	10.2
300	7,744 f	5.6	9.5
360	8,336 g	7.6	9.6
420	8,533 h	2.4	8.7
480	8,591 h	1.0	7.7

[1] Means with same letter do not differ at the .05 level of significance.

The number of N applications had a distinct effect on distribution of forage growth throughout the season (Figure 6). Yield from single N applications was highest from mid-October to February and lowest the remainder of the season compared to the two- and three-way applications. Three-way split applications of N resulted in lowest yield in the first half of the season and highest in the second half. Yield response to the two-way split application was intermediate to that of the other applications throughout the season.

There was a yield increase with each 60-pound increment of N through 420 pounds per acre (Table 17). The relatively high yield of forage without

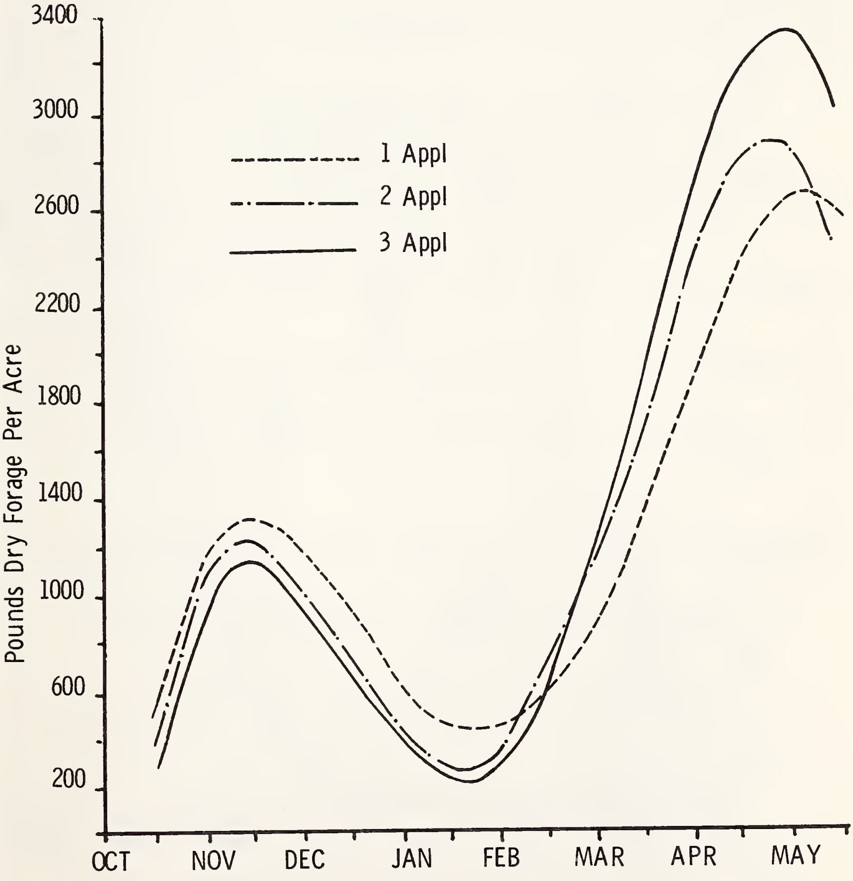


Figure 6.—Mean effect of N applications on seasonal yield of oat-ryegrass-clove mixture. Average of 5.7 clippings per year over 6 years.

applied N was probably due to the contribution made by clover. Clover growth was not conspicuous in plots that received more than 120 pounds of N per acre. The contribution of clover, particularly at the zero and lower levels of applied N, may account for the relatively low percentage increase per increment of added N, and the low amount of forage produced per pound of applied N. Based on the percentage increase (1.0 percent) of the last increment of added N, it appears that 420 pounds of N per acre approached the maximum amount this crop mixture could utilize.

Effect of N rates on the seasonal distribution of forage growth are shown in Figure 7. Growth patterns throughout the season for all N rates were essentially the same. Generally, yield was consistently higher throughout

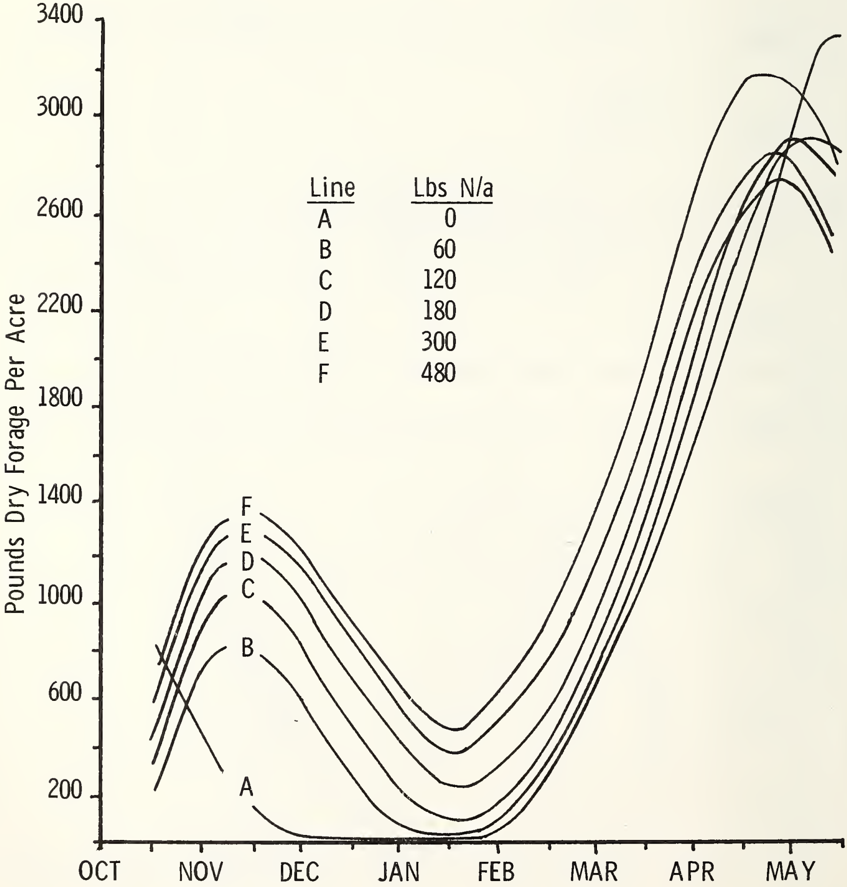


Figure 7.—Mean effect of N rates on seasonal yield of oat-ryegrass-clover mixture. Average of 5.7 clippings per year over 6 years.

the season with each increment of N. In October and November there was a conspicuous lack of growth in the forage that did not receive applied N. Such a management scheme would not normally supply forage for grazing until early March.

Effects of Nitrogen Application Interval on the Forage Yield of an Oat-Ryegrass-Clover Mixture

A study was conducted to determine the effect of nitrogen (N) applied at monthly intervals on total yield and yield distribution of an oat-ryegrass-clover mixture. Moregrain oats, *Avena sativa* L.; annual ryegrass, *Lolium multiflorium* (L.) Lam.; and common crimson clover, *Trifolium incarnatum* L., were planted in combination as the test crop.

The crop mixture was planted with a conventional grain drill. Oats were planted in 7-inch drills at a rate of 112 pounds per acre. Ryegrass and clover were broadcast at rates of 30 and 20 pounds, respectively. Plantings were made in early October.

Phosphorus (P_2O_5) and potassium (K_2O) were applied at a rate of 140 pounds each per acre with the grain drill at planting.

Two rates of N were applied in all combinations with seven different intervals of application. Intervals were based on 30-day increments, beginning at the planting date and extending over the season. The treatment that did not receive any applied N served as the check.

The crop was harvested to a 3-inch stubble when the forage averaged 10 inches in height.

Yield means for the two rates of N, averaged over all frequencies, and the check treatment are shown in Table 18.

Yield increased significantly with the use of applied N. However, yield of the plots without applied N was more than half that of the plots that

Table 18.—Mean effects of applied nitrogen (N) on the dry forage yield of an oat-ryegrass-clover mixture, 5-year average[1]

N, lbs/a	Yield, lbs/a
0	4,361 a
200	6,855 b
400	7,404 c

[1] Means with same letter do not differ at the .05 level of significance.

received 400 pounds. These data indicate that clover contributed considerably to the total yield of the plots that did not receive any applied N.

Overall effects of N rate on the growth distribution of the crop mixture throughout the season are shown in Figure 8. Forage production was consistently greater over the season in response to 400 pounds of N per acre than it was with 200 pounds. The decline in growth during mid-winter is generally attributed to low temperature.

The data indicate that the growth rate was consistent over the season for the forage mixture that did not receive applied N. On the contrary, however, growth rate was more inconsistent over the season among years in the absence of applied N than with it, resulting in a predicted uniform growth rate.

Total yields were numerically close in response to application intervals averaged over N rates (Table 19). Lowest yields occurred with a single application of N applied at planting and two applications at a 180-day interval. The second application of the 180-day interval was made in mid-April, which generally is considered too late in the season for a growth response.

Growth distributions of the crop mixture as affected by N application

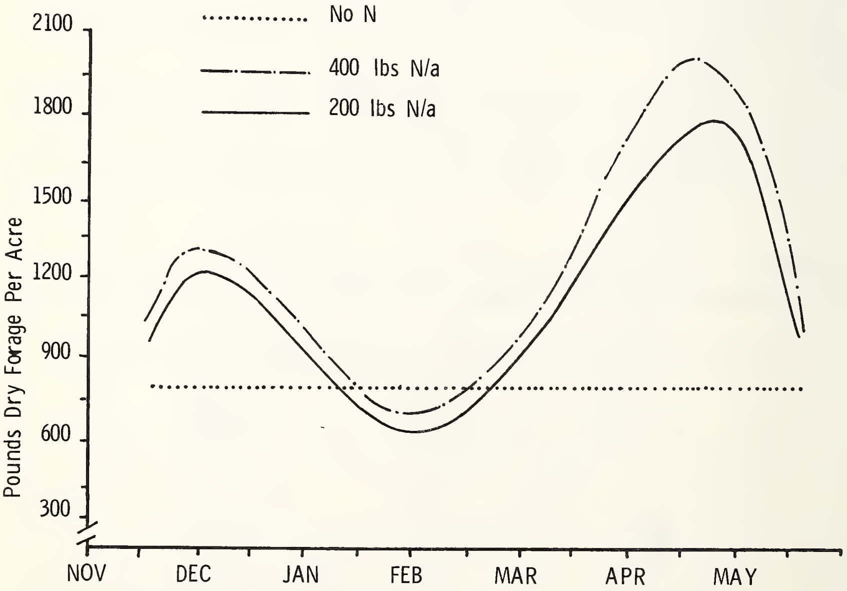


Figure 8.—Mean effect of N rates, averaged over six intervals of application, on seasonal yield of an oat-ryegrass-clover mixture. Average of 5.4 clippings per year over 5 years.

Table 19.—Mean effects of nitrogen (N) application interval on dry forage yield of an oat-ryegrass-clover mixture, 5-year average[1]

N Application No.	N Application Interval	Yield, lbs/a
1	At planting	6,908 a
7	30 days	7,237 b
4	60 days	7,204 b
3	90 days	7,201 b
2	120 days	7,194 b
2	150 days	7,340 b
2	180 days	6,821 a

[1] Means with same letter do not differ at the .05 level of significance.

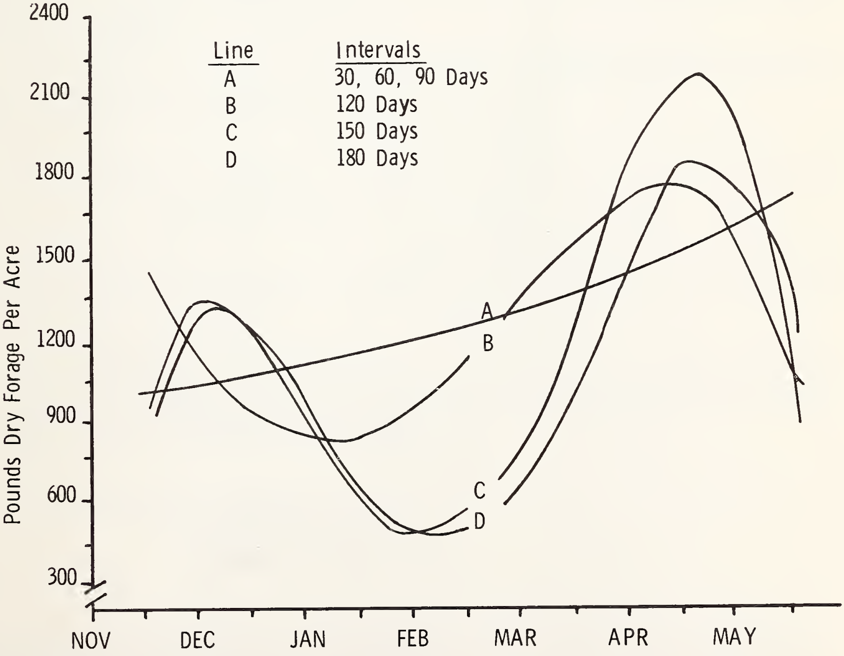


Figure 9.—Mean effect of interval of N application on seasonal yield of an oat-ryegrass-clover mixture. Average of 5.4 clippings per year over 5 years.

intervals are shown in Figure 9. N application intervals of 30, 60, and 90 days (line A) provided the most uniform growth over the season. These data indicate that N applied in three or more applications, spaced at no greater than 90-day intervals was superior in maintaining uniform forage growth to N applied at intervals greater than 90 days.

Generally, the greater the number of days between the first and second N application the less the forage growth in January and February.

Effects of Nitrogen Rates and Application Combinations on the Forage Yield of an Oat-Ryegrass-Clover Mixture

A 3-year study was conducted to determine the effects nitrogen (N) rates applied in different application combinations would have on the yield of a forage crop mixture. The mixture included Moregrain oats, annual ryegrass, and common crimson clover. The crop was planted in mid-September each year with a conventional grain drill.

Phosphorus (P_2O_5) and potassium (K_2O) were applied annually at a rate of 140 pounds each per acre at planting.

Application combinations of the applied N and the time of applications were as follows:

Application combination of N	Time of N application
1	All N applied at planting
¾ + ¼	¾ of N applied at planting, ¼ in mid-February
⅔ + ⅓	⅔ of N applied at planting, ⅓ in mid-February
½ + ½	½ of N applied at planting, ½ in mid-February
½ + ¼ + ¼	½ of N applied at planting, ¼ in late December, ¼ in early March
⅓ + ⅓ + ⅓	⅓ of N applied at planting, ⅓ in late December, ⅓ in early March

The mean effects of N rate and application combination on yield are shown in Table 20. Yield was increased by approximately 1,000 pounds of forage per acre with each increment of N. Total yield was relatively high

Table 20.—Mean effects of nitrogen (N) rate and application combination on yield of an oat-ryegrass-clover mixture, 3-year average[1]

N rates, lbs/a	Yield, lbs/a	Application combination	Yield lbs/a
0	5,112 a	1 at planting	6,909 a
80	6,009 b	3/4 + 1/4	7,208 ab
160	7,399 c	2/3 + 1/3	7,370 bc
240	8,262 d	1/2 + 1/2	7,614 bcd
300	9,197 e	1/4 + 1/4 + 1/4	7,694 cd
		1/3 + 1/3 + 1/3	7,745 d

[1] Means with same letter in yield columns do not differ at the .05 level of significance.

for the forage that did not receive any applied N, indicating that clover probably contributed substantially to the total yield.

Total yield increased with combinations that distributed N more equally over the season, but not to a large extent.

Mean effects of N rates on seasonal distribution of growth are shown in Figure 10. Yield of the forage that did not receive applied N was lowest over the season.

Yield distributions for the 80-, 160-, and 240-pound rates were similar, each declining during mid-winter. Yield at the 300-pound rate reflected a more uniform growth rate throughout the season.

Mean effect of N application combinations on yield distribution are shown in Figure 11. Yield was uniform from mid-October to mid-February in response to one application of N applied at planting. Applied N, particularly at the heavier rates, probably stimulated growth of the grasses in the fall, which suppressed establishment of the clover. Absence of clover in the spring, in conjunction with N being applied in the fall, resulted in lower yield in March and April.

Yield distribution from combinations involving two N applications were essentially the same throughout the season. Yield distributions involving three N applications were also similar.

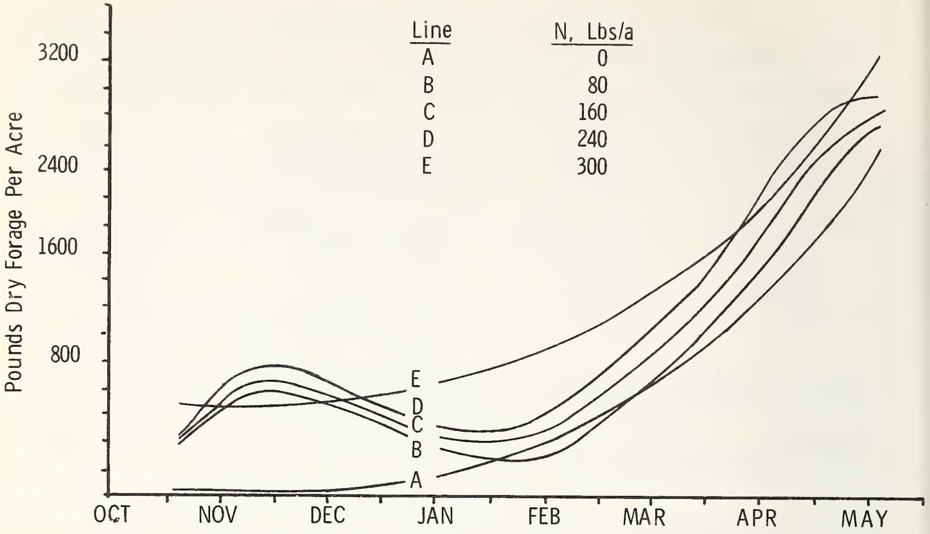


Figure 10.—Mean effect of N rates, averaged over six application combinations, on seasonal yield of an oat-ryegrass-clover mixture. Average of six clippings per year over 3 years.

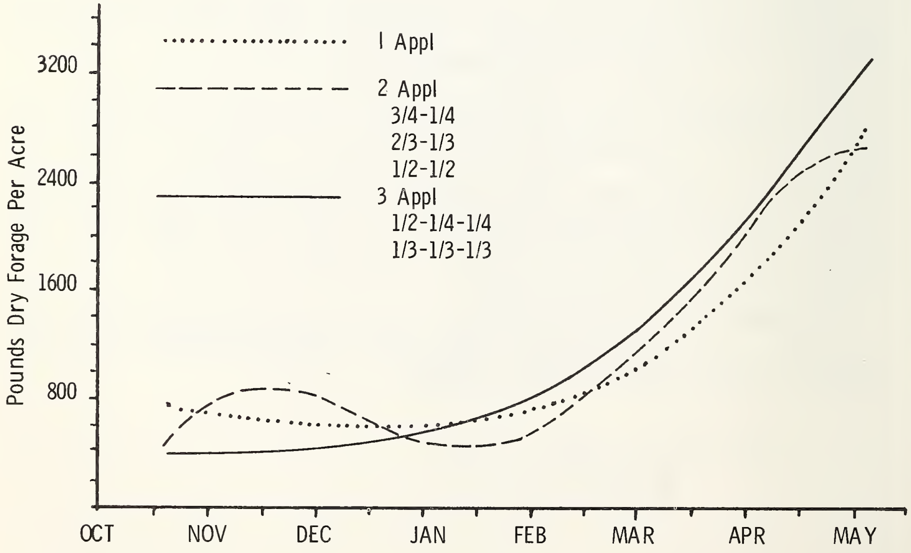


Figure 11.—Mean effect of N applications on seasonal yield of an oat-ryegrass-clover mixture. Average of six clippings per year over three years.

Sodium Nitrate and Ammonium Nitrate Compared on a Pound-For-Pound Basis as a Source of Nitrogen for Forage Production

A 3-year study was conducted to compare sodium nitrate ($NaNO_3$) to ammonium nitrate (NH_4NO_3) as a source of N for an oat-ryegrass-clover mixture. The materials were compared on a pound-for-pound basis at five rates. Both materials were popular and competitive as sources of N, particularly during the 1950's.

A crop mixture of Moregrain oats, annual ryegrass, and common crimson clover was planted with a conventional grain drill. Phosphorus (P_2O_5) and potassium (K_2O) were applied at a rate of 140 pounds each per acre at planting. Nitrogen was applied in a two-way split application, half at planting and half in mid-February.

Rates of N material used and yield data are shown in Table 21. Yield was higher with NH_4NO_3 than $NaNO_3$ at each rate tested. Yield increases were significant through the application of 1,000 pounds of $NaNO_3$ and through 800 pounds of NH_4NO_3.

Nitrogen utilization was equally efficient from both N sources at the 200-pound per acre rate. At the 400-pound rate, NH_4NO_3 produced almost 1 pound more forage per pound of applied N than did $NaNO_3$. From 600 to 1,000 pounds of material per acre, $NaNO_3$ produced more forage per pound of applied N than did NH_4NO_3. One important point of consideration is that for the respective rates of material per acre, NH_4NO_3 supplied slightly more than twice as much available N than did $NaNO_3$.

Clover probably contributed to total yield up through the application of 800 pounds of $NaNO_3$ and through 400 pounds of NH_4NO_3.

Table 21.—Yield response of an oat-ryegrass-clover mixture to $NaNO_3$ and NH_4NO_3, 3-year average[1]

N Material, lbs/a	Yield, lbs/a		Lbs. forage/lb N	
	$NaNO_3$	NH_4NO_3	$NaNO_3$	NH_4NO_3
None	--- 5,784 a ----			
200	6,329 b	6,918 c	17.0	16.9
400	6,724 c	7,871 d	14.7	15.6
600	7,551 d	8,319 e	18.4	12.6
800	7,817 d	9,154 f	15.9	12.6
1,000	8,313 e	9,391 f	15.8	10.8

[1] Means with same letter do not differ at the .05 level of significance.

Comparison of Nitrogen Sources for Forage Production

A study was conducted to evaluate commercially available sources of nitrogen (N) for forage production of an oat-ryegrass-clover mixture.

Nitrogen was applied in both a single and a two-way split application at a rate of 160 pounds per acre the first 2 years and 200 pounds the third year. Phosphorus (P_2O_5) and potassium (K_2O) were applied at rates of 80 pounds each per acre the first 2 years and 100 pounds each the third year.

Nitrogen sources and the respective yields are shown in Table 22. As an average of all sources, single versus split applications of N had little effect on total yield. The largest reduction in yield occurred with urea applied in split applications. Increased yields with split applications instead of single applications were highest with $(NH_4)_2$ SO_4 and $NaNO_3$ (Chilean). Yield differences due to source of N probably are not as important as cost of N, equipment needed for storage, and application.

Table 22.—Comparison of nitrogen (N) sources on forage yield of an oat-ryegrass-clover mixture[1]

N Source	% N	N Applications Single	N Applications Split
		- - - Yield, lbs/a	- -
None		3,513 a	
$NaNO_3$ (Chilean)	16.0	7,316 abc	7,746 c
$NaNO_3$ (Synthetic)	16.0	7,762 c	7,591 bc
NH_4NO_3	33.5	7,061 a	7,255 ab
Uran	33.0	7,152 ab	7,151 ab
3-year average		7,323 A	7,436 A
$(NH_4)_2$ SO_4	21.5	6,987 ab	7,531 b
Urea	46.0	6,971 ab	6,229 a
NH_3	82.0	6,267 a	6,724 a
2-year average		6,742 A	6,828 A

[1] Means with same letter in year average groups do not differ at the .05 level of significance.

Effects of Applied Nitrogen on an Oat-Ryegrass Mixture

A 5-year study was conducted to measure the yield response of an oat-ryegrass mixture to nitrogen (N) rates applied in combination with various rates of phosphorus (P_2O_5)and potassium (K_2O). Treatment effects on yield, mineral content, and qualitative components were reported in Louisiana Agricultural Experiment Station Bulletin Number 680. Treatment effects on nutrient removal and soil chemical changes were reported in Louisiana Agricultural Experiment Station Bulletin Number 690.

Moregrain oats and Gulf ryegrass were seeded at rates of 112 pounds per acre drilled and 20 pounds per acre broadcast, respectively.

All of the phosphorus and potassium were applied and incorporated into the soil prior to planting. Half of the N was applied at planting, and one-fourth in both mid-December and mid-March.

Harvests were made when the forage averaged about 10 inches high. Forage was cut to a stubble height of 4 inches the first 4 years, and 3 inches the fifth year.

Mean effects of applied N and K_2O on total yield are shown in Table 23. Yield increased significantly as N application was increased from 200 to 400 pounds per acre. Significant yield increases to the higher rates of K_2O were obtained in combination with the higher rates of N.

Table 23.—Mean effects of applied N and K_2O on dry forage yield of an oat-ryegrass mixture, 5-year average[1]

N,	K_2O, lbs/a			
Lbs/a	100	200	300	Av
	- - - - - - - Forage lbs/a	- - - - - - -	- - - - - - -	- - - - - - -
200	7,501 a	7,732 b	7,790 b	7,674 A
300	8,054 c	8,610 e	8,682 e	8,448 C
400	8,449 d	9,053 f	9,324 g	8,942 E
Av	8,001 B	8,465 C	8,599 D	

[1] Means with same letter do not differ at the .05 level of significance.

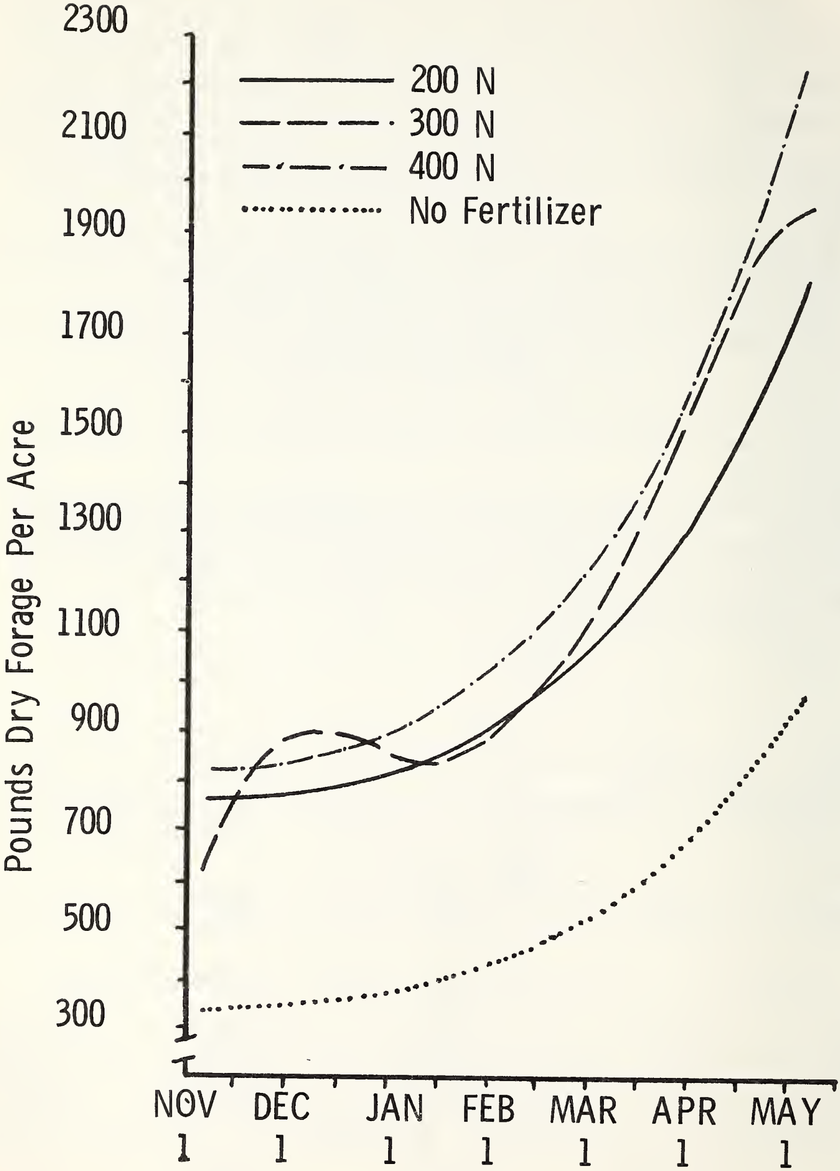


Figure 12.—Seasonal mean effects of applied N on the forage yield of an oat-ryegrass mixture. Average of seven clippings per year over five years.

Seasonal growth distribution curves of the forage mixture in response to the mean effects of applied N are shown in Figure 12. Yield throughout the season was generally increased with each increase in applied N. Distribution of yield over the season was not affected by amount of N applied. The slope of the response curve of the non-fertilized forage was essentially the same as those of the fertilized forage.

The Influence of a Nitrification Inhibitor on the Forage Yield of an Oat-Ryegrass Mixture

A study was conducted to compare the yields of an oat-ryegrass mixture from applications of ammonium sulfate, $(NH_4)_2 SO_4$, with and without a nitrification inhibitor (Dow 163).

Nitrogen (N) was applied at a rate of 200 pounds per acre. Both phosphorus (P_2O_5) and potassium (K_2O) were applied at a rate of 100 pounds per acre.

The treatments compared in this study and respective total dry matter yields are shown in Table 24. As an average, yield response to untreated ammonium sulfate was equal to or superior to that of the treated N material. Generally, the number of applications of N had a greater effect on yield than whether the N material was treated or untreated.

Although yields in response to untreated N were among the highest, there was a tendency for yields to increase as the inhibitor content was increased from 0.2 to 0.4 percent.

Yield Response of Double-Cropping Ryegrass and Millet to Nitrogen Sources and Rates

A study was conducted to compare the effectiveness of sulphur-coated urea (SCU) as a slow release source of nitrogen (N) with that of other N sources. The objective was to identify a source of N which when applied at planting would provide a uniform release of available N over the season to avoid excessive uptake by the plants and losses by leaching, run-off, and volatilization.

Gulf ryegrass and Gahi-1 pearl millet were the crops used. Phosphorus (P_2O_5) and potassium (K_2O) both were applied at a rate of 200 pounds per acre in the fall. None was applied in the spring.

Nitrogen treatments and yields are shown in Table 25. Higher solubility percentages of SCU generally resulted in higher ryegrass yield and lower millet yield. Combined yield was about 1,000 pounds per acre higher for SCU-10 than for SCU-30, at both rates of applied N.

Ammonium nitrate and urea, when applied in split applications, in most cases were equal to or superior to SCU. However, urea applied in a single application resulted in lowest yield of both crops.

Additional N applied in the spring increased yield, but the pounds of

Table 24.—Effects of ammonium sulfate treated with 'Dow 163' nitrification inhibitor on the forage yield of an oat-ryegrass mixture

Dow 163 treated $(NH_4)_2SO_4$	Nitrogen No. of applications	 Method applied	Yield lbs/a
---	---	---	2,611
None	1	Drilled	8,074
None	2	Drilled	8,298
None	3	Drilled	8,377
None	7	Drilled	8,157
0.2%	1	Drilled	7,111
0.2%	2	Drilled	7,931
0.3%	1	Drilled	7,137
0.3%	2	Drilled	8,488
0.4%	1	Drilled	7,776
0.4%	2	Drilled	8,758
1.6%	1	Drilled	7,527
1.6%	2	Drilled	7,314
None	2	Broadcast	8,559
0.4%	2	Broadcast	8,064
1.6%	2	Broadcast	8,707
LSD at the .05 level of significance			670

forage produced per pound of applied N were generally lowest.

There apparently was no carry-over of fall-applied N at the 200-pound rate on millet yield, as indicated by the check treatment yield. At the 400-pound rate of fall-applied N, carry-over N accounted for from 500 to 2,000 pounds of additional millet yield.

These data indicate that there is, at the present, no commercially available source of N that can be applied in a single application that will provide yields equal to two or more applications of a given rate over a period of several months.

Table 25. Dry forage yield response of ryegrass and millet to nitrogen (N) sources and rates

Source of N	Application of N lbs/a		Yield, lbs/a		Combined Yield	Combined lbs forage per lb N
	Fall	Spring	Ryegrass	Millet		
Check	---	---	2919	3595	6514	---
SCU-10*	200	---	5165	4664	9829	16.6
SCU-20	200	---	5364	3163	8527	10.1
SCU-30	200	---	5632	3345	8977	12.3
NH_4NO_3	200	---	5454	3403	8857	11.7
NH_4NO_3**	200	---	5921	3143	9064	12.7
Urea	200	---	5074	3390	8464	9.7
Urea**	200	---	5925	3716	9641	15.6
NH_4NO_3**	200	100	6203	4530	10733	14.1
NH_4NO_3**	200	200	6472	4737	11209	11.7
NH_4NO_3**	200	400	6206	6483	12689	10.3
SCU-10*	400	---	7030	5226	12256	14.4
SCU-20	400	---	7334	4147	11481	12.4
SCU-30	400	---	7165	4707	11872	13.4
NH_4NO_3	400	---	7061	5097	12158	14.1
NH_4NO_3**	400	---	7670	5413	13083	16.4
Urea	400	---	6607	4216	10823	10.8
Urea**	400	---	7349	4614	11963	13.6
NH_4NO_3**	400	100	6936	5751	12687	12.3
NH_4NO_3**	400	200	7059	6669	13728	12.0
NH_4NO_3**	400	400	7552	7391	14943	10.5
LSD at .05			279	1104		

*SCU - sulphur coated urea. The respective number is the % of N solubility in 100° F water at 7 hours.

**N applied in 3-way split.

Summary

Millet, oats, ryegrass, bahiagrass, and bermudagrass all responded to 400 or more pounds of applied N per acre. Yields of corn and forage sorghum did not increase with applications of more than 200 pounds of N.

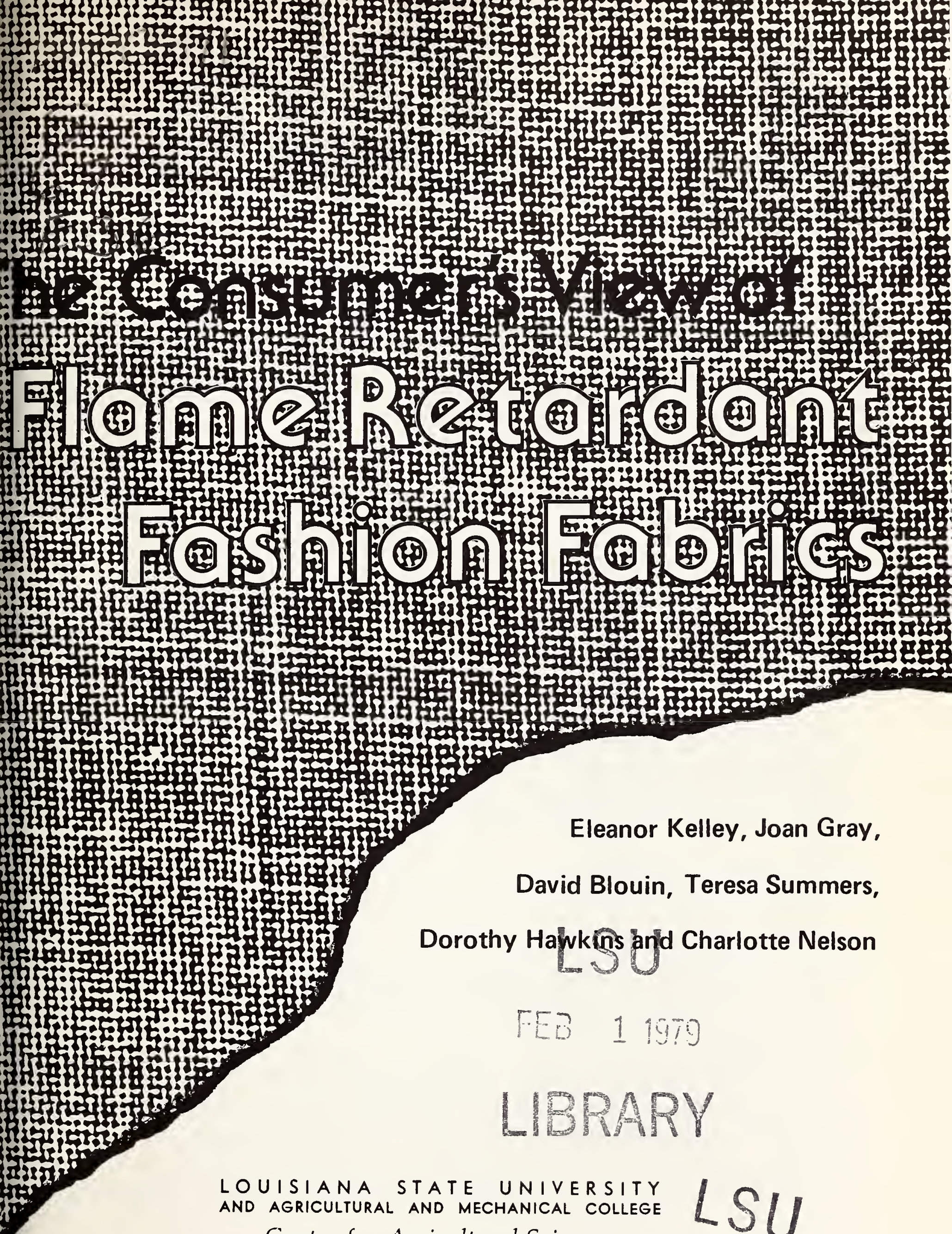
Nitrogen applied in split applications did not alter total yield as compared with a single application. Splitting N applications on bahiagrass and oat-ryegrass mixtures did alter the growth distribution throughout the season. As N applications were increased from one to three, peak dry matter production of bahiagrass shifted from mid-July to early September. The yield distribution of an oat-ryegrass mixture tended to be more uniform through the season with three N applications than with fewer applications.

A nitrification inhibitor showed no consistent beneficial effect on the yield of an oat-ryegrass mixture or of millet.

In forage crops which included a clover it was apparent that the clover contributed largely to total yield only when less than 120 pounds of N was used.

Small yield differences due to source of applied N indicate that N should be purchased based on the cost of N per pound and not on source. Other points to consider include costs of handling and of application.

These data indicate that with good management practices, grasses respond well to applied N. The economic value of applied N is determined not only by forage yield but also by monetary value of the salable product derived from the forage.



he Consumer's View of Flame Retardant Fashion Fabrics

Eleanor Kelley, Joan Gray,
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December 1978

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The Consumer's View Of Flame Retardant Fashion Fabrics

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Introduction

Extensive human and economic losses from burn injuries prompted Congress to enact legislation to eliminate from the marketplace easily ignitable and flash-burning fabrics. The first Flammable Fabrics Act (FFA), passed in 1953, was amended in 1967 to include interior furnishings, paper, plastic, and other materials used in wearing apparel and interior furnishings. The Secretary of Commerce was authorized to set additional standards when necessary to protect consumers from dangerous fabrics, and the Consumer Product Safety Commission, activated in 1973, was given responsibility for regulating flammable fabrics. Products covered to date include carpets and rugs, April 1970; small carpets and rugs, December 1970; mattresses, June 1973; children's sleepwear, sizes 0-6X, July 1973, and children's sleepwear, sizes 7-17, January 1975 *(12)*[4].

Problems faced by manufacturers and retailers in implementing FFA guidelines are well established in the literature. Flame retardant (FR) finishes may be applied to fibers that are not inherently FR. However, problems involved in providing flame retardant fabrics (FRF) include the logistical complications involving additional equipment, personnel, and testing facilities; product losses due to sampling, and increased processing time due to soaking fabrics in chemical baths or injecting chemicals into the fibers when they are being mixed *(18)*.

Flame retardant finishes may affect the performance characteristics and the aesthetic characteristics of textiles. Conversely, other finishing procedures, such as dyeing, the types and tightness of fabric structures, and the combination of fibers, affect fabric flammability. Fabric flammability is also affected by the characteristics of garment designs, such as loose-fitting styles or body-conforming styles, and the characteristics incorporated in garment construction, such as types of thread and seam finishes. Since FR finishes modify to some extent the inherent fabric properties, no FR finish will allow fabrics to maintain all of their other positive qualities *(15, 11, 22, 13, 2, 10, 14)*.

---

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[4] Italic numbers in parentheses refer to Literature Cited, page 39.

The multiplicity of production problems indicates that manufacturers and consumers must make choices among the total range of fabric properties available, and manufacturers believe consumers must understand clearly the trade-offs involved in the consumer movement *(23)*.

The competitive market system in America is based on the belief that the consumer should be free to choose from among the available products those that best fulfill his needs *(5)*. However, this freedom of choice may be gradually reduced in fashion fabrics as the FFA is enforced. When consumers were given a choice between FRF and non-FRF in children's sleepwear, they often chose the lower priced garments of non-FRF *(24)*. Retailers have expressed concern that when consumers are denied a choice in a given garment category, they will select substitutions from other garment categories in which non-FRF are still available to fulfill their needs *(3)*.

Government officials and consumer experts believed that apparel with flame retardant characteristics would be a welcome innovation in light of the emphasis on health and safety in our society *(8)*. They also suggested that consumer education is the key to consumer acceptance of FRF *(25, 16, 18)*.

This is in accord with the marketing principle that an individual's attitude about a phenomenon can be changed only after new information is provided *(16)*.

Since much of the literature about FRF focuses on the manufacturers' problems, the purpose of this research was to explore the consumer viewpoint of the FRF issue. This report centers on four aspects of the research — the consumers' knowledge, experiences, attitudes, and priorities regarding FRF. Data for the research were collected in two studies conducted approximately 1 year apart. In the first study, conducted in 1976, one objective was to determine the extent of the respondents' knowledge of the problems involved in providing protection from fabric-related burns. The findings revealed that the majority of the women had limited knowledge of and limited experience with these problems. Therefore, in the second study an experimental situation was designed to see if providing information about burn propensities, FFA legislation, and FRF finishes would make a difference in consumer attitudes toward and priorities for protection. The study was based on the assumption that providing this information would increase the consumers' knowledge about the flammable fabrics issue.

Description of Studies

The highest incidence of clothing burns occurs in the East South Central States, the ''Burn Belt,'' where the use of fireplaces and space heaters has been prevalent *(1)*. The two studies were conducted in the same urban area in south Louisiana, an area within this ''Burn Belt.'' The community also contained large petrochemical complexes where burn propensities are greater than in some other industries. The researchers believed that residents in such a setting would have a general knowledge of burn situations even if they were not aware of the FFA and of FRF.

The mail surveys included cross-sections of the female population. Approximately 50,000 households were recorded among the some 150,000 residents in the 1970 federal census.

Study I Sample

A systematic random sample of 1,221 households, slightly more than 2 percent of the households, was generated from every 75th name in the telephone directory. If the 75th name was a business establishment or a suburban residence, the next name was selected. The additional households were drawn initially because the researchers recognized that a simple random sample of the telephone book would yield a higher proportion of upper social class respondents. To create a balanced sample, the initial sample was first stratified according to the five wealth ratings listed in *Cole's Directory (9)* and then reduced to approximately 2 percent of the sample by systematic random elimination of households in each of the top two wealth ratings. (These evaluations are based on prestige and value of property, and wealth ratings on a given street change as property values change.) This yielded 1,031 households, with approximately 200 in each of the top four ratings and 250 in the lowest rating. In addition to over sampling in the lowest rating, special versions of the fixed-response questions were developed with indigenous words of the lower social classes to further insure responses from them, and these questionnaires were mailed to households in the two lower wealth ratings. One month after the initial mailing of the questionnaires, follow-up postcards were mailed to the sample thanking them if they had responded and requesting returns if they had not. This second mailing contained phone numbers of the researchers so additional copies of the questionnaires could be mailed to those consumers who requested them. Some consumers called to explain why they had not returned the questionnaires rather than returning them. Reasons included no female in household, disinterest in the topic, or the belief that answers would be of no value due to lack of knowledge of the topic.

The independent variable questions were designed to obtain data on FRF knowledge, experience, and demographic characteristics, whereas the dependent variable questions were designed to elicit information regarding consumer attitudes toward FRF and priorities for FRF. The final count after the postcard mailings yielded 204 respondents who returned questionnaires with usable responses in some of these sets of questions. The variation in the number of respondents in the data sets is reflected in the numbers recorded in the tables. Only those respondents who provided a complete set of information pertinent to the data in a given segment of the analysis were included in that specific segment of the analysis.

Study II Sample

The questionnaires issued to the Study I sample contained questions designed to determine the extent of the respondents' previous knowledge about the FFA and FRF. The accompanying cover letters merely discussed textiles in general to minimize bias regarding providing information about the flammable fabrics issue. These questions were eliminated from Study II, and only the information concerning the demographic characteristics of the respondents and their experience, attitudes, and priorities regarding FRF was elicited. In Study II, the second systematic random sample of households was generated in the same manner as the Study I sample. All duplicate households from Study I were eliminated and replaced with the next appropriate listing in the telephone directory.

In the Study II sample, half of the households in each wealth rating — approximately 100 in each stratum except the lowest (125 in it) — were assigned to the experimental group and half to the control group. The experimental group received a cover letter that included information about the FFA and FRF, ostensibly to increase their knowledge of the problems involved in providing protection from fabric-related burns, whereas the control group received the Study I cover letter that merely discussed consumer reactions to textile products in general. The initial mailing and follow-up postcards resulted in almost equal numbers of usable returns in each treatment group — 103 in the experimental group and 92 in the control group. Chi-square analyses showed there were no significant differences between either the reported personal and family characteristics or the experiences of the women in the experimental and control groups. Data from the control and treatment groups were also subjected to analysis of variance (ANOV) tests to check for group differences in attitudes and priorities. Because no significant differences were found, the data were pooled for all of the analyses presented in this report.

Profile of Respondents: Study I and Study II

Previous researchers have found that several demographic characteristics are associated with propensity to be involved in burn accidents: age (highest among young children, the elderly, and girls ages 6 to 12); social class (highest among lowest stratum); housing (highest among those who live in poor, particularly crowded conditions); race (highest among nonwhites); region (highest frequency in East South Central states, the "Burn Belt," where fireplaces and space heaters are commonly used); and physical condition (highest among handicapped persons of all ages) *(1, 18, 19, 21, 26)*. Several of these variables, along with other standard demographic variables, were considered in this study.

The demographic characteristics of the respondents in Study I and Study II were each subjected to Chi-square tests to compare the known characteristics of the two groups. Approximately three-fourths of the respondents (76%, Study I; 75%, Study II) were married. Nearly 60 percent of the women in both studies (59%, Study I; 58%, Study II) reported having children living at home. Of those families containing children, 69 percent in Study I and 58 percent in Study II had children in the age groups considered to have a high propensity to be burn victims — males, ages 0 to 5, and females, ages 0 to 12. Only a small percentage of the families (9%, Study I; 10%, Study II) included members over age 65 — the other high burn propensity age group.

The largest proportion of the women in both studies were between the ages of 18 and 34 (39%, Study I; 44%, Study II). Approximately one-fourth of the women (25%, Study I; 23%, Study II) were age 55 and older. Slightly more than half (52%, Study I; 54%, Study II) had at least a high school education, and an additional third (33%, Study I; 31%, Study II) had completed college. Nearly half of the main wage earners (44%, Study I; 44%, Study II) had high school diplomas and possibly some college, while well over one-third (40%, Study I; 38%, Study II) had college degrees. According to the criteria of Hollingshead's *Two Factor Index of Social Position (17),* most respondents were classified either in the two upper social class levels (27%, Study I; 31%, Study II) or in the two lower social class levels (47%, Study I; 40%, Study II). The majority of the wage earners were employed in either professional and semiprofessional occupations (39%, Study I; 45%, Study II) or in clerical and skilled manual positions (34%, Study I; 25%, Study II).

To determine the women's experiences with FRF, a modified version of the diffusion model developed by Bohlen *(6)* was used. Beal and Rogers *(4)* used his original model to study the adoption of new fabrics. Consumers may have a cluster of general information regarding fires, burns, and fabrics on which to form an attitude toward FRF even though they do not have specific information about flame retardance, so a *not aware* category was added. The awareness and information stages were also combined as *have seen* and the application and trial categories were treated as *considered buying* and *purchased*, respectively. The adoption stage was omitted since not enough FR products were available to enable full adoption of FRF.

Since the respondents were classified only in the highest experience level checked, each experience level constitutes a mutually exclusive category. When the FRF experiences of the women in Study I and Study II were subjected to analysis of variance, no significant differences were found. Only a small percentage of the respondents (10%, Study I; 19%, Study II) were *not aware* of FR garments. Of those women who were aware of the availability of FR garments, approximately one-third (35%, Study I; 30%, Study II) *had seen* them, while a smaller number (15%, Study I; 11%, Study II) had *considered buying*; and over half (50%, Study I; 59%, Study II) had actually *purchased* at least one FR garment. The number of respondents who had *purchased* an FR garment, however, represented slightly less than half of the total number of repondents in each study (45%, Study I; 44%, Study II).

Experiences with Burn Victims

Several of the women in Study I mentioned that their experiences or lack of experiences with burn victims were reflected in their responses. As a result of these responses, an additional series of experience questions was included in Study II to determine if intimate, especially repeated, contact with burn victims would make a profound impact on a person's attitudes and priorities for protection from fabric-related burns. The women were asked to indicate the number of times their family members, relatives, or friends had been injured by fire. Their answers were used to establish weighted rankings with the Likert technique *(20)*. The possible combinations of responses in the questionnaire were scored to form a continuous variable ranking from 1 to 9. The ranks, with least involvement having a rank of 1 and most involvement having a rank of 9, were as follows: no one involved; relative or friend involved once; family member involved once; relatives or friends involved more than once; family members involved more than once; relative or friend and family member both involved once; relatives or friends involved more than once, family member involved once; relative or friend involved once, family members involved more than once; and relatives or friends and family members both involved more than once. When Chi-square analyses were calculated, no significant differences occurred in the control and experimental groups' experiences with burn victims. Therefore, the two groups were combined for further analyses.

Almost 50 percent of the women had never been involved with a burn victim. Twenty-eight percent of those who had were involved once with a family member, and 40 percent were involved once with a friend or relative. Only 15 percent of the respondents had had multiple experience with family members and friends as burn victims.

FRF Findings: Study I

Knowledge

The flame retardance knowledge questions focused on: (1) general knowledge of clothing burns, including major sources of ignition and types of persons most susceptible to being involved in clothing related fires; (2) the FFA; (3) potential flammability of diverse fiber and fabric variations, and (4) effect of selected factors in laundering procedures on retention of FR protection.

The maximum knowledge score, 28, was calculated with the Likert technique. The scale was based on a simple summation of one point for each correct response to the fixed-alternative questions. Actual scores ranged between 3 and 22 with an overall mean of 12.3.

The majority of the women knew general information such as the major source of fires (e.g., space heaters, 82.11%), and they knew that the FFA was in effect for children's sleepwear sizes 0-14 (57.36%). However, only a few knew about (1) the burning rate of fabrics with different fiber contents and structures (e.g., polyester vs. nylon, 17.17%); (2) the effect of laundering procedures on retention of flame retardancy (e.g., laundering in soft water, 4.12%), and (3) the actual implementation of the FFA in products other than children's sleepwear (e.g., mattresses, 13.71%).

The lack of knowledge about the FFA was evident in the nonusable data as well as in the usable data. A number of elderly women indicated they were not answering the questionnaires because they believed that flame retardancy was "a problem for young folks," and they believed their reponses would be of little value. Some women wrote that they had not seen the FR finishes, and most important, were not interested in them. These notes and telephone responses as well as the relatively low knowledge scores in the usable data seem to indicate consumer ignorance of and indifference toward the FRF issue.

Frequently respondents try to provide the information they believe the researchers desire. To minimize such bias, some questions about the Permanent Care Trade Rule, the Textile Fiber Identification Act, and the Fur Products Labeling Act were included with the questions about current implementation of the FFA. Knowledge of the FFA implementation was presented in five categories — adult, all children's clothing, children's sleepwear sizes 0-14, carpets, and mattresses. When the consumers' knowledge of each of these five FFA categories was compared with their knowledge of each of the other legislative acts, a number of significant differences occurred.

Chi-square analyses revealed significant differences in the number who knew about the enforcement of permanent care labeling and those who knew about the enforcement of the FFA in children's sleepwear 0 to 14

($X^2 = 24.40365$, $p<.0001$, df = 1), carpets ($X^2 = 6.46081$, $p<.01$, df = 1), and mattresses ($X^2 = 6.62434$, $p<.009$, df = 1). More of the women (57%) knew about enforcement of the FFA in children's sleepwear than about permanent care labeling (47%), but less knew about enforcement of the FFA in the remaining garment (FFA not enforced for children's clothing, 19%, or for adult clothing, 25%) and home furnishing categories (mattresses, 14%; carpets, 14%). Many of the responses coded as incorrect were simply "don't know."

When responses about enforcement of the FFA were compared with responses about the Fur Products Labeling Act, significant differences in knowledge regarding enforcement occurred in all categories of FR products except mattresses — adult clothing ($X^2 = 6.939$, $p <.008$, df = 1), children's clothing ($X^2 = 4.5364$, $p <.03$, df = 1), children's sleepwear ($X^2 = 12.8987$, $p <.0004$, df = 1), and carpets ($X^2 = 7.0442$, $p <.007$, df = 1). Only 30 percent correctly recognized the enforcement of the Fur Products Labeling Act, but this percentage was higher than the percentages (cited in the previous paragraph) who correctly identified FR enforcement in all aspects of the FFA coverage except children's sleepwear.

The same trend continued when the responses were compared with responses about enforcement of the Textile Fiber Products Identification Act (TFPIA). Almost half (45%) of the respondents correctly recognized enforcement of the TFPIA. Highly significant differences appeared in recognition of the TFPIA enforcement and recognition of enforcement of the three garment aspects of FR products, adult wear ($X^2 = 22.763$, $p <.0001$, df =1), all children's clothing ($X^2 = 11.7809$, $p<.0007$, df =1), and children's sleepwear sizes 0 to 14 ($X^2 = 30.6627$, $p <.0001$, df = 1).

Experiences

The consumers' low scores regarding knowledge of the problems involved in providing protection from fabric-related burns may have been a result of the limited range of FR products available on the market. Until FRF is available in many garment categories, consumers' experience with these products will be limited. Levels of the consumers' experiences were determined from a modified version of the diffusion model developed by Bohlen *(6)*. Consumers may have a cluster of general information and thereby an opinion regarding burn sources and injuries, federal legislation, and fabric characteristics, even if they do not have information regarding FRF *per se*. Therefore, the *not aware* category was considered along with *have seen* (awareness and information), *considered buying* (application), and *purchased* (trial). The adoption stage was omitted due to limited availability of FR garments. Respondents were classified in only one — the highest experience level, making each experience level a mutually exclusive category. The actual percentages of respondents in each category were: *not aware,* 10 percent; *have seen,* 31 percent; *considered buying,* 13 percent and *purchased,* 45 percent.

It was hypothesized that the consumers' knowledge of problems involved in providing protection from fabric-related burns would be associated with their experience. But analysis of variance calculations indicated experience was not a significant source of variation for knowledge scores ($F = .561$, $p < .05$). Mean knowledge scores clustered around 12 in all experience levels, indicating relatively low knowledge regardless of experience (*not aware,* $\bar{X} = 12.38$; *have seen,* $\bar{X} = 11.73$; *considered buying,* $\bar{X} = 12.72$; and *purchased,* $\bar{X} = 12.56$).

Attitudes Toward FRF

Attitudes were explored to determine if a relationship existed between the consumers' FRF knowledge and experience and their FRF attitudes. Three components were included in the FRF attitude items — attitudes toward availability of FRF, attitudes toward federal government regulations regarding FRF, and atttitudes toward potential monetary and time costs involved in acquiring and maintaining FRF. Some of the items in each component set were presented negatively, others positively, and all were randomly arranged throughout the set of 23 items.

The maximum possible attitude score, derived with the Likert scaling technique based on a simple summation of responses on a five-point scale to each attitude item, was an indication of a strong positive attitude toward FRF. The maximum score, 120, was the sum of the component scores of FRF availability (45), government regulations of FRF (40), and monetary and time costs to have and maintain FRF (35). However, the actual total scores ranged only from 43 to 115 with a mean of 76.97. ANOV calculations revealed that responses to each of the 23 items were highly discriminating ($p < .0001$) between those respondents who had total attitude scores in the highest 25 percent of the sample and those in the lowest 25 percent of the sample.

Pearson product-moment correlations were calculated to explore the relationships between attitudes in one component set and in each of the other sets. As shown in Table 1, the correlations were highly significant ($p < .0001$) between total attitudes and each of the three components and between each of the component sets and all other components. However, neither total attitudes nor component sets of attitudes were related to knowledge (Table 2). This is probably because the respondents' knowledge scores were generally much lower than their attitude scores. For example, the overall knowledge mean of 12.3 represented approximately the 40th percentile of the maximum possible knowledge score of 28; whereas, the overall total attitude mean of 76.95 represented approximately the 70th percentile of the maximum possible total score of 115.

Table 1.—Pearson product-moment correlations between consumers' total attitudes and each component set of attitudes regarding flame retardant fabrics (FRF)

Attitudes	Attitude toward availability	Attitude toward government regulations	Attitude toward monetary and time costs
Total attitude			
n[1]	101	101	101
r[2]	0.9333****	0.8921****	0.8667****
Attitude toward availability			
n		104	103
r		0.7464****	0.7549****
Attitude toward government regulations			
n			105
r			0.6201****

[1] n = number of observations.

[2] r = correlation coefficient.

****Significant at .0001 level.

Table 2.—Pearson product-moment correlations between consumers' attitudes regarding FRF and their knowledge of FRF

Attitudes	Number of observations	Correlation coefficient
Total attitude	73	0.0339[1]
Attitude toward availability	78	–0.0557
Attitude toward government regulations	77	0.0758
Attitude toward monetary and time costs	77	–0.0437

[1] All values not significant.

Analysis of variance also revealed that the consumers' experience was not a significant source of variation for their total FRF attitudes ($F = 1.6201$, $p < .05$). The total attitude mean scores for this ANOV were high at all levels of experience (*not aware* = 73.63, *have seen* = 75.00, *considered buying* = 71.09, and *purchased* = 80.35). Since this same patterning of high mean scores appeared when each component set of attitudes was analyzed, none of the 12 F values in the analyses of the component sets of attitudes was significant.

Idealistic Priorities for FRF

As Scotese *(23)* notes, manufacturers cannot provide all of the fabric properties simultaneously in one product, and consumers must make choices among the total range of fabric properties available. Thus, the importance of the FR characteristic to consumers was explored in two ways: idealistically, when considered alone, and realistically, when considered among a range of other desirable properties.

The idealistic priority question was designed to elicit responses regarding the consumers' priorities for the FR characteristic when no restrictions were imposed on other fabric or garment characteristics. Respondents were asked to indicate the clothing categories — *sleepwear, casual wear, dressy wear, outer wear,* and *"other"* — for which they felt the FR characteristic was needed. These were given for six age-sex groups — children 1 to 5 years, males 6 to 12, females 6 to 12, teenagers, adults, and elderly (65 and above). *Work uniforms* were also included in the adult group. An idealistic priority score was attained for each respondent using the Likert scaling technique. The scores were derived by summing one point for each time a respondent indicated a desire for the FR characteristic. The maximum score of 37 would indicate the respondent believed that all garments should be made FR for all age-sex groups. The actual range of scores among the respondents was 1 to 37, with a total idealistic priority mean of 19.6552, or a mean at the 53rd percentile of the maximum possible score.

Since the patterning of future enforcement of the FFA by garment categories and age groups has not been finalized by the Consumer Product Safety Commission, the consumers' priorities were statistically analyzed for all possible combinations of age groups and garment categories.

Pearson product-moment correlations were calculated to determine (1) if consumers' total idealistic priorities for FR garments were consistent with their idealistic priorities for each age and garment category, and (2) if these subgroup priorities were consistent with each other. To explore these relationships, the data were programmed to check for relationships between the total idealistic score and each garment and age subscore. First, calculations were made for each of the six garment categories, disregarding age groups, to see if the respondents' idealistic priorities for each garment category were associated with their total idealistic priorities for the FR characteristic. Next, correlations between their total idealistic priorities and each of their age-sex priorities were explored. Consumers' total idealistic priority scores were highly correlated with each garment and each age-sex subscore ($p < .0001$), as shown in Table 3.

When data were analyzed by subcategories, each of the age-sex and garment subpriority scores was correlated with each of the other age-sex and garment subpriorities, and highly significant relationships were again found. Subpriorities scores for six garment types were correlated with the six age-sex subgroups and all 36 relationships were highly significant ($p < .001$). Priority scores for each age-sex group were highly correlated with all other age-sex group priorities ($p < .01$). Subpriorities for each garment category were significantly correlated with each of the other

Table 3.—Pearson product-moment correlations between consumers' total idealistic priorities for FRF and their idealistic priorities for FRF for specific garment types and for specific age groups

Categories	Number of observations	Correlation coefficient
GARMENT TYPES:		
Sleepwear	116	0.5548****
Casual wear	116	0.7884****
Outer wear	116	0.7387****
Dressy clothes	116	0.8642****
Underwear	116	0.8095****
Other	116	0.5503****
AGE GROUPS:		
Children 1-5	116	0.8000****
Males 6-12	116	0.9089****
Females 6-12	116	0.8994****
Teenagers	116	0.9026****
Adults	116	0.9002****
Elderly	116	0.8181****

****Significant at .0001 level.

garment categories with one exception. There was no correlation between *sleepwear* and the *''other''* garment category (''other'' was mostly work clothing). Tables showing the subpriority data — a total of 66 analyses — were omitted due to space limitations.

Realistic Priorities for FRF

Investigation of the technical literature indicates that other fabric characteristics may have to be traded off to obtain the FR characteristic through special finishes. In the realistic priority question, respondents were asked to appraise the importance they would place upon having the FR characteristic if having it meant they had to sacrifice some of the other fabric or garment characteristics.

The characteristics listed were *color, long wearing, odorless, soft, comfort, ease of care, permanent press, shrink control, ornamentation,* and *design lines.* Consumers were asked if they would be willing to give up these characteristics in each of four garment categories — *sleepwear, casual wear, dressy wear,* and *underwear* — for each of the six age-sex groups mentioned above. Using the Likert scaling technique, one point was summed for each indication of willingness to sacrifice a characteristic. The maximum score of 240 would indicate that the respondent was willing to give up all 10 of the garment characteristics in all four of the garment categories for all six of the age-sex groups to have the FR characteristic. The actual realistic scores ranged from 0 to 240, demonstrating

Table 4.—Pearson product-moment correlations between consumers' total realistic priorities for FRF and their realistic priorities for FRF for specific garment types and for specific age groups

Categories	Number of observations	Correlation coefficient
GARMENT TYPES:		
Sleepwear	111	0.9175****
Casual wear	111	0.9024****
Dressy clothes	111	0.8832****
Underwear	111	0.8806****
AGE GROUPS:		
Children 1-5	111	0.8564****
Males 6-12	111	0.9156****
Females 6-12	111	0.9445****
Teenagers	111	0.9229****
Adults	111	0.8904****
Elderly	111	0.9102****

****Significant at .0001 level.

again the wide diversity among respondents. Yet the group mean score was relatively low ($\bar{X} = 57.72$), only at the 24th percentile of the maximum possible realistic score.

Again, all possible combinations of age and garment categories were statistically analyzed. Pearson product-moment correlations were calculated to explore relationships between (1) total realistic priorities and age-sex and garment subpriorities, and (2) each age-sex and garment subpriority versus all other age-sex and garment subpriorities. First the data were programmed to explore the relationship between the total priority score and each of the subpriority scores in three ways. Total priority scores were correlated with scores for (1) specific garment categories, (2) specific age-sex categories, and (3) specific garment categories by specific age-sex groups. Then all possible combinations of garment by age subscores were calculated.

Of the 451 correlations, 446 were significant at the .0001 level, four at .001, and one at .01. Thus, the women had highly consistent priorities at all levels of analysis. The correlations between the total realistic priority scores and each garment and each age-sex subgroup are shown in Table 4. The remaining correlation tables were omitted due to space.

Knowledge and Priorities

The women's idealistic and realistic FRF priority scores were correlated with their knowledge scores to determine if they were significantly related. Correlations were calculated to determine the association between knowledge and each of the following priority scores: total idealistic priority, total realistic priority, each of the six idealistic garment category priorities, each of the six idealistic age-sex group priorities, each of four realistic garment priorities, each of six age group realistic priorities, and each of 24 realistic individual garment categories. No significant associations with knowledge appeared in any of the idealistic or in any of the realistic priorities scores.[5]

Experience and Priorities

The consumers' idealistic priorities for the FR characteristic — total score, six age-sex category scores, and six garment category scores — were analyzed to determine if level of experience with FR finishes was a significant source of variation in their assessment of the need for the FR characteristic. None of the eight ANOV tests revealed significant differences.[5]

When the 11 realistic priority scores — one total, six age-sex, and four garments — were explored with experience, one significant difference appeared; a significant difference ($p < .05$) occurred in the consumers' priority for the FR characteristic for children ages 1 through 5. The mean realistic priority score for the FR characteristic for children 1 through 5 was higher in the *not aware* level ($\bar{X} = 18.0$) than in any of the other experience levels (HS: $\bar{X} = 8.74$; CB: $\bar{X} = 11.00$; P: $\bar{X} = 8.68$).

The respondents' age-sex group FRF priorities within a specific garment category were compared with experience, and two of the 24 comparisons yielded significant relationships. Experience was related to consumers' priorities for *dressy wear* for children ages 1 through 5 ($F = 3.72$; $< .05$) and for *casual wear* for children ages 1through 5 ($F = 3.28$, $p < .05$). Surprisingly, respondents who had the most experience with the FR finish had the lowest mean realistic priority scores for *casual wear* (NA: $\bar{X} = 4.6667$; HS: $\bar{X} = 2.1935$; CB: $\bar{X} = 2.5$; P: $\bar{X} = 1.9149$). The realistic priority mean score for *dressy clothes* for children ages 1 through 5 was higher among those who were *not aware* of FRF ($\bar{X} = 4.1111$) than were the mean scores among respondents in the other experience levels (HS: $\bar{X} = 1.6129$; CB: $\bar{X} = 2.3$; P: $\bar{X} = 1.4681$).

Attitudes and Priorities

Many significant associations occurred between respondents' FRF attitude scores and their idealistic priority scores. The total attitude score and each of the three component attitude scores — FRF availability, government regulations of FRF, and time and money sacrifices to have and maintain FRF — were correlated with the consumers' total idealistic priority scores ($p < .0001$). Twenty-three of the 24 correlations between their total attitude scores and the three component attitude scores and each of the six idealistic garment priority scores were highly significant ($p<.0001$). Only the time and monetary attitude and the idealistic priority for FRF in *outerwear* were not correlated. The 24 correlations between each of the six idealistic age-sex priority scores and the total attitude and each of the three component attitude scores were highly significant ($p<.0001$).

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[5] Statistical data where no significant differences occurred have been omitted.

When each of the four attitude scores was correlated with the total realistic priority scores, constituting a total of four correlations, only the component attitude score regarding time and monetary costs needed to maintain the FR finish was significantly related to the total realistic FRF priority ($r = .2353$, $p <.05$).

Garment and age subpriorities were correlated with the total and with the three component attitude scores in three ways. The four attitude scores were correlated with: (1) the four garment subpriorities; (2) the six age-sex subpriorities, and (3) each of the six age-sex groups within a specific garment category. Although all attitude scores were relatively high (ranging between the 60th and 70th percentiles), and all priority scores were quite low (ranging between the 10th and 20th percentiles), a number of significant correlations were found. The majority of the significant correlations involved those garment categories and age-sex categories that are statistically less likely to be involved in burn accidents — *casual* and *dressy wear* and adults and teenagers. Examination of score ranges indicated there was greater variation within these four low propensity subcategories than in the categories more likely to be associated with burn accidents. In these high propensity categories, the scores tended to cluster at high levels, thereby resulting in significant correlations.

Demographic Characteristics and Knowledge

Ten demographic variables — marital status, age of respondent, occupation of main wage earner, education of respondent, education of main wage earner, number of children living in home, presence of males ages 0-5 and females ages 0-12 in the home, presence of males ages 6-18 and females ages 13-18 in the home, persons over 65 living in the home, and social class — were explored as possible sources of variation in the knowledge, experience, attitudes, and priorities of the consumers.

There were no significant differences in the women's knowledge by any demographic variable. Mean scores from the analyses of variance clustered in the variable categories between 11 and 14, regardless of the demographic variable under consideration.

Demographic Characteristics and Experience

When Chi-square analyses were conducted, several significant differences occurred among experience levels. Computations regarding presence of younger children, one of the groups with high propensity to be burn victims, yielded a highly significant difference in experience ($X^2 = 34.6530$, $p<.00001$, df = 3). Among those who had small children, the greatest number *had purchased* FRF; whereas, among those who had no small children, the greatest number *had only seen* FRF. Analysis of number of children in the family also yielded a significant difference in experience ($X^2 = 8.6978$, $p <.03$, df = 3). Nearly 50 percent of the women had purchased FRF. Of these purchasers, a higher proportion of those with three or more children at home (68%) than of those with two or less children at home (41%) had purchased FRF.

A highly significant difference in FRF experience ($X^2 = 19.9799$, $p<.002$, df = 6) appeared when the women's own ages were explored. The largest proportion of FRF purchasers (59.4%) were in the youngest age group (18 through 34). Of those 55 and older, the largest proportion (49%) *had only seen* FRF. Highly significant differences in FRF experiences were also found by education of the women ($X^2 = 21.0153$, $p<.01$, df = 6) and by education of the main family wage earner ($X^2 = 16.0962$, $p<.001$, df = 6). Among the women themselves, the largest numbers either *had seen* FRF or actually *had purchased* FRF, and in each of these two experience levels approximately the same proportion were high school graduates as were college graduates. This same general patterning of experience and education occurred when education of the main wage earner was the variable.

Demographic Characteristics and Attitudes

None of the demographic variables had an effect on total attitude scores, as revealed by analyses of variance. However, having children in the younger age group, one of the groups with high propensity to be burn victims, bordered on significance ($F = 2.6862$, $p <.10$). Apparently the consumers' negative attitudes toward government regulations negated significance for the total attitude scores because having younger children was a significant source of variation in the other two components of the FRF attitudes, FRF availability, ($F = 3.9153$, $p <.05$) and monetary time and costs ($F = 6.2820$, $p <.02$). More of the women who had young children ($\overline{X} = 32.26$) than those who had no young children ($\overline{X} = 28.41$) had positive attitudes toward availability of FRF. More of the ones who had young children ($\overline{X} = 27.29$) than those who had no young children ($\overline{X} = 23.54$) also had positive attitudes toward expending money and time if necessary to have FRF.

Calculations of demographic differences regarding attitudes toward monetary and time expenditures to have FRF either produced significant differences or bordered on significance in three additional variables. Age of the women was a significant source of variation in attitudes toward expending money and time ($F = 4.7547$, $p<.01$); the higher the age, the more positive the attitudes toward money and time expenditures to have

FRF (ages 18 to 34, $\bar{X} = 22.37$; 35 to 54, $\bar{X} = 26.69$; 55 and over, $\bar{X} = 27.19$). Education of respondents bordered on being a significant source of variation ($F = 2.7188$, $p < .07$). High school graduates had the highest positive attitudes toward monetary and time expenditures for FRF ($\bar{X} = 27.38$), followed by those with less than high school education ($\bar{X} = 25.25$) and college graduates ($\bar{X} = 25.25$). Having children in the older age group, one of the categories with low propensity to be burn victims, also bordered on being a significant source of variation ($F = 2.8962$, $p < .09$) in attitudes toward monetary and time expenditures to have FRF. Those consumers whose families included older children had a lower positive attitude toward monetary and time expenditures ($\bar{X} = 23.88$) than did those whose families contained no older children ($\bar{X} = 26.95$).

Demographic Characteristics and Priorities

ANOV tests were first conducted to see if the demographic variables were significant sources of variation in the respondents' idealistic priorities. None was a significant source of variation when the total idealistic priority score was used. However, when the priority scores were broken down into the specific age-sex and garment categories, some demographic variables were significant sources of variation. When priorities for FRF for specific age-sex groups were considered, one difference — for the *elderly* age-sex group — bordered on significance. Based on a maximum subscore of 6, married respondents had a higher mean score priority for the FR characteristic for the *elderly* age group ($\bar{X} = 4.35$) than did the respondents who were not married ($\bar{X} = 3.28$; $F = 3.90$; $df = 1$; $p < .0519$). One significant difference in idealistic priorities for FR *sleepwear* was seen between those respondents who had children classified in the low propensity age groups and those who had no children in this age classification. Mean priority scores in the *sleepwear* category were lower for respondents who had children in the age-sex groups with low propensity to be burn victims ($\bar{X} = 5.10$) than for respondents who did not have children in the low propensity categories ($\bar{X} = 6.22$; $F = 5.11$; $df = 1$; $p < .0267$).

The second set of analyses of variance were calculated to see if the same 10 demographic variables were significant sources of variation in the respondents' realistic priorities. Two significant differences in total realistic priorities were found — among respondents in the different age groups (Table 5), and among respondents whose main family wage earners were classified in the different educational levels (Table 6). Older respondents, age 55 and above, had higher FRF priority mean scores (Table 7) than those under 35 years of age and those between 35 and 54 years of age. Respondents whose main family wage earners had one or more college degrees had the highest FRF priority mean scores (Table 8), followed in descending order by those whose family wage earners had

Table 5.—Analyses of variance of realistic priorities of consumers for the FR characteristic, classified by total priority and by age group, garment category, and age by garment category subpriorities, with age of respondent as source of variation

Realistic priorities	Source of variation	Degrees of freedom	Mean squares	F values
TOTAL PRIORITY		2	6,762.46	3.6371*
GENERAL AGE PRIORITIES				
Children 1-5	Age	2	157.88	3.2023*
	Error	69	49.30	
Females 6-12	Age	2	246.86	4.0024*
	Error	68	61.68	
Elderly[1]	Age	2	282.97	4.0911*
	Error	69	69.41	
GARMENT PRIORITIES				
Sleepwear[2]				
Casual wear	Age	2	853.60	6.0476**
	Error	67	141.15	
Dressy wear	Age	2	804.97	5.2355**
	Error	67	153.75	
Underwear[2]				
GARMENT PRIORITIES BY SPECIFIC AGE GROUPS				
Sleepwear[3]				
Casual wear				
Children 1-5	Age	2	28.33	6.5341**
	Error	69	4.34	
Males 6-12	Age	2	21.93	4.6472*
	Error	69	4.72	
Females 6-12	Age	2	30.63	6.4333**
	Error	68	4.76	
Teenagers	Age	2	17.46	3.8112*
	Error	67	4.58	
Adults	Age	2	13.95	3.1347*
	Error	69	4.45	
Elderly	Age	2	34.63	6.1576**
	Error	69	5.62	
Dressy wear				
Children 1-5	Age	2	20.54	4.8387*
	Error	69	4.24	
Males 6-12	Age	2	26.60	5.4091**
	Error	69	4.92	
Females 6-12	Age	2	20.54	4.0274*
	Error	68	5.10	
Teenagers	Age	2	19.94	4.0513*
	Error	67	4.92	
Adults	Age	2	15.52	3.4076*
	Error	69	4.55	
Elderly	Age	2	32.16	5.8591**
	Error	69	5.49	
Underwear[3]				

[1] No significant differences occurred in remaining age groups.

[2] No significant differences occurred in remainng garment categories.

[3] No significant difference occurred in any age group for these two garment categories.

*Significant at .05 level.

**Significant at .01 level.

Table 6.—Analyses of variance of realistic priorities of consumers for the FR characterisitic, classified by total priority and by age group, garment category, and age by garment category subpriorities, with education of family wage earner as source of variation

Realistic priorities	Source of variation	Degrees of freedom	Mean squares	F values
TOTAL PRIORITY		2	6,833.51	3.6753*
GENERAL AGE PRIORITIES				
Children 1-5	Education	2	221.91	4.5010*
	Error	69	49.30	
Males 6-12	Education	2	243.41	4.1543*
	Error	69	58.59	
Females 6-12[1]	Education	2	236.52	3.8348*
	Error	68	61.68	
GARMENT PRIORITIES				
Sleepwear	Education	2	748.86	5.1960**
	Error	67	151.05	
Underwear[2]	Education	2	685.41	3.6559*
	Error	67	187.48	
GARMENT PRIORITIES BY SPECIFIC AGE GROUPS				
Sleepwear				
Children 1-5	Education	2	25.14	6.0524**
	Error	69	4.15	
Males 6-12	Education	2	35.36	7.0376**
	Error	69	5.02	
Females 6-12[1]	Education	2	38.85	7.4677**
	Error	68	5.20	
Underwear				
Children 1-5	Education	2	19.18	3.5967*
	Error	69	5.33	
Males 6-12	Education	2	25.50	4.0216*
	Error	69	6.34	
Dress wear[3]				
Casual wear[3]				

[1] No significant differences occurred in remaining age groups.

[2] No significant differences occurred in remaining garment categories.

[3] No significant differences occurred in any age group for these two garment categories.

*Significant at .05 level.

**Significant at .01 level.

completed high school and those whose family wage earners had less than high school educations.

When garment subpriorities were classified according to demographic variables, several significant differences were found. Respondents in the different age categories had significantly different FRF priorities for the *casual wear* and *dressy wear* categories. As shown in Table 7, those in the oldest age group (55 and older) had the highest FRF priority mean scores for *casual wear* and those in the two younger age groups had the lowest scores. A similar pattern, also visible in mean scores in Table 7,

Table 7.—Adjusted mean scores of realistic priorities of consumers for the FR characteristic, classified by total priority and by age group, garment category, and age by garment category subpriorities, with consumers classified by age of respondent

	Age of respondent					
Realistic priorities	18-34		35-54		55 and above	
	n	Mean	n	Mean	n	Mean
TOTAL PRIORITY	31	21.5467	29	26.2207	23	60.3125
GENERAL AGE PRIORITIES						
Children 1-5	32	4.9119	30	6.4368	23	11.0953
Females 6-12	31	4.5201	30	5.2490	23	11.8577
Elderly[1]	32	3.2558	30	4.4270	23	11.2740
GARMENT PRIORITIES						
Casual wear	31	3.1991	29	4.5590	23	16.8485
Dressy wear[2]	31	1.3848	29	7.0278	23	15.8111
GARMENT PRIORITIES BY SPECIFIC AGE GROUPS						
Sleepwear[3]						
Casual wear						
Children 1-5	32	1.0416	30	1.3990	23	3.5694
Males 6-12	32	0.7842	30	0.9999	23	2.9696
Females 6-12	31	0.7328	30	1.0040	23	3.3180
Teenagers	31	0.4457	29	0.5498	23	2.3583
Adults	32	−0.0886	30	−0.2658	23	1.4779
Elderly	32	0.2447	30	1.0881	23	3.1708
Dressy wear						
Children 1-5	32	0.5984	30	1.7233	23	2.8907
Males 6-12	32	0.4417	30	1.5115	23	3.0510
Females 6-12	31	0.4059	30	1.2561	23	2.6943
Teenagers	31	−0.0311	29	1.2524	23	2.2362
Adults	32	−0.3412	30	0.2089	23	1.6146
Elderly	32	0.3720	30	0.9611	23	3.1353
Underwear[3]						

[1] No significant differences occurred in remaining age groups.

[2] No significant differences occurred in remaining garment categories.

[3] No significant differences occurred in any age group for these two garment categories.

occurred in their priorities for *dressy clothes*. Mean scores for *sleepwear* and *underwear* and choices among these three age groups were more closely clustered (Table 7). For *sleepwear,* the range of means was from a high of 16.21 for respondents ages 55 and over to a low of 9.86 for respondents ages 18 to 34. The same pattern occurred for *underwear*, with 11.43 as the high mean and 7.10 as the low mean. Thus, among the *outer wear* categories, more diversity of opinion was seen among the age groups.

Again, as in the total realistic priorities, education of the main wage earner was a significant source of variation in the respondents' realistic priorities for having the FR characteristic in some of the selected garment categories (Table 6). Significant differences were found for both the

Table 8.—Adjusted mean scores of realistic priorities of consumers for the FR characteristic, classified by total priority and by age group, garment category, and age by garment category subpriorities, with education of family wage earner used to categorize consumers

	College and beyond		Completed high school		Less than high school	
Realistic priorities	n	Mean	n	Mean	n	Mean
TOTAL PRIORITY	36	66.0340	39	49.7303	8	–7.6844
GENERAL AGE PRIORITIES						
Children 1-5	38	13.0716	39	9.5036	8	–0.1312
Males 6-12	38	12.4394	39	9.4397	8	–1.4328
Females 6-12[1]	37	13.0748	39	9.0950	8	–0.5431
GARMENT PRIORITIES						
Sleepwear	36	22.3081	39	13.5226	8	–1.9621
Underwear[2]	36	16.7785	39	14.5335	8	–5.9309
GARMENT PRIORITIES BY SPECIFIC AGE GROUPS						
Sleepwear						
Children 1-5	38	3.6722	39	2.0268	8	–0.6068
Males 6-12	38	4.3103	39	2.0802	8	–0.5479
Females 6-12[1]	37	4.6797	39	2.3138	8	–0.4153
Underwear						
Children 1-5	38	3.5030	39	2.9694	8	–0.3431
Male children 6-12[1]	38	3.0612	39	2.9432	8	–1.1586
Dressy wear[3]						
Casual wear[3]						

[1] No significant differences occurred in remaining age groups.

[2] No significant differences occurred in remaining garment categories.

[3] No significant differences occurred in any age group for these two garment categories.

sleepwear and *underwear* categories; in both categories, respondents whose main family wage earner had completed college had the highest mean priority score, followed in order by high school graduates and those who had less than a high school education (Table 8).

When the realistic age-sex priorities were classified according to demographic variables, five tests were run for each demographic characteristic — one general priority and one age-sex subpriority for each of the four specific garment categories. Respondent's age was a source of variation in many of these comparisons. For general age-sex group subpriorities, respondent's age was a significant source of variation among those age-sex groups with high propensities to be burn victims — children ages 1 to 5 and the elderly, ages 65 and older (Table 5). Apparently the differences occurred because the mean priority scores of the 55-and-older age group, shown in Table 7, were substantially higher (ranging from 10 to 12) than those of the younger age groups (ranging from 4 to 6). When priorities for *casual wear* and *dressy wear* were classified by respondents' age, differences in all six garment categories were significant (Table 5). Again, the 55-and-older age group consistently had the highest mean scores (Table 7). As seen in the garment subpriorities, when the age priorities mean scores were high among the two younger respondent groups as well as among the over-55 age group, no significant differences appeared. This patterning also occurred in the priorities for *sleepwear* and *underwear* when age of the respondent was the source of variation.

Educational level of the family's main wage earner also accounted for significant differences in the respondents' total FRF priorities for each of the three age-sex groups under 12 years of age (Table 6). Although total priority scores consistently increased with progressively higher levels of education for all six comparisons between age groups (Table 4), the increase was greater among those three age-sex groups under 12 years of age where significant differences were seen.

Similar mean score increases created significant differences among priorities for *sleepwear* in the same three age-sex groups under 12 years of age when priorities for the specific garment categories were calculated (Tables 6 and 8). When age-sex priorities for *underwear* were examined, significant differences were found in priorities for children ages 1 to 5 and male children ages 6 to 12. A similar patterning of higher mean scores occurred among those respondents whose main wage earners had higher levels of education (Table 6 and 8).

FRF Findings: Study II

Attitudes Toward FRF

Study I included 23 attitude items. Each of these 23 items was highly discriminating ($p<.0001$) when subjected to analysis of variance to compare the responses of those respondents in Study I who had the highest 25 percent of the total scores with those who had the lowest 25 percent of the scores. Therefore, in Study II the two items from each component set of attitudes in which the scores of the respondents were most closely clustered were deleted. One of the remaining items was used in two of the component sets, and each item was designed on a five-point scale. Therefore, the maximum possible total score in Study II was 90, as derived with the Likert scaling technique based on a simple summation of responses to each item. This score indicated a strong positive attitude toward FRF. The maximum possible component scores of 30 each for FRF availability, government regulations of FRF, and monetary and time costs to have and maintain FRF, were summed to give the maximum possible score of 90. However, actual total scores among the respondents ranged only from 20 to 81, with a mean of 49.97.

To determine the relationships between attitudes in one component set

Table 9.—Pearson product-moment correlations of consumers' total attitudes and subattitudes regarding FRF vs. each attitude category

Attitudes	Attitude toward availability	Attitude toward government regulations	Attitude toward monetary and time costs
Total attitude			
n[1]	159	159	159
r[2]	.9497**	.8904**	.9087**
Attitude toward availability			
n		161	161
r		.8309**	.8004**
Attitude toward government regulations			
n			162
r			.6639**

[1] n = sample size.

[2] r = correlation coefficient

**Significant at .01 level.

and in each of the other sets, Pearson product-moment correlations were calculated. Total attitude scores were highly correlated ($p<.001$) with each of the three component scores, shown in Table 9, as were correlations between each of the component sets and all other component sets.

Analyses of variance revealed that consumers' experiences with FR garments were a highly significant source of variation in the respondents' attitudes regarding FRF availability ($p<.01$), and were a significant source of variation in their total attitudes ($p<.05$), in their attitudes toward government regulations ($p<.05$), and in their attitudes toward monetary and time costs of FRF ($p<.05$). Respondents who had considered buying but had not purchased FR garments had the highest total attitude mean score ($\overline{X}$ = 59.86). The other respondents' scores clustered in descending order from highest to lowest mean scores in the *not aware* (X = 53.11), *purchased* (X = 49.14), and *aware* (X = 46.38) categories. A similar trend in each of the subattitude mean scores in the four experience categories was also found.[6]

The researchers were also interested in whether the respondents' attitudes toward FR garments were related to their experiences with burn victims. Total attitude scores (maximum possible = 90) ranged from 45.65 to 64.20 among the nine experience levels. The subattitude scores (maximum possible = 30) were similar in range; availability ranged from 15.50 to 22.00, government regulation ranged from 15.63 to 22.20, and monetary and time costs ranged from 16.73 to 22.60. Analyses of variance were used to determine differences in total attitude scores and subattitude scores for the nine levels of experience with burn victims. There were highly significant differences among experience levels ($p < .005$) in the respondents' total attitude scores and the availability subattitude scores, while a significant difference ($p < .05$) was found in the monetary cost subattitude scores. Attitudes toward government involvement also bordered on significance ($p < .10$). Generally, the respondents who had the most experience with burn victims had the higher attitude scores, while those respondents who had few experiences or no experience with burn victims had the lowest scores.

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[6] Subattitude mean scores were omitted due to space.

Idealistic Priorities for FRF

The same idealistic priority question described in Study I was explored in Study II, and the same method of computing each woman's idealistic priority score was used in Study II. The actual idealistic priority scores among the respondents spanned the total possible range of scores, 0 to 37. with a mean score of 15.57.

As in Study I, the consumers' priorities were statistically analyzed for all possible combinations of age groups and garment categories. Pearson product-moment correlations were calculated to explore the relationships between the total idealistic score and each garment and age subscore to determine (1) if consumers' total idealistic priorities for FR garments were consistent with their idealistic priorities for FR garments for each age and garment category, and (2) if these subgroup priorities were consistent with each other. The relationship between respondents' idealistic priorities for each of the six garment categories, disregarding age-sex groups, and their total idealistic FRF priorities were explored first. Correlations between their total idealistic priorities and each of their age-sex priorities were then calculated. Highly significant correlations ($p < .0001$) occurred between the respondents' total idealistic priority scores and each garment and each age-sex subscore (Table 10).

Highly significant correlations ($p < .0001$) were again found when each of the age-sex and garment idealistic subpriority scores was compared with each of the other age-sex and garment idealistic subpriorities. The six age-sex subgroup scores were correlated with the six garment subpriority scores, and all 36 relationships were highly significant ($p < .0001$). Each age-sex group priority score was highly correlated ($p < .0001$) with all other age-sex group priority scores. Subpriorities for each garment category were highly correlated ($p < .005$) with each of the other garment categories.[7]

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[7] Tables showing subpriorities data were omitted.

Table 10.—Pearson product-moment correlations between consumers' total idealistic priorities for FRF and their idealistic priorities for FRF for specific garment types and for specific age groups

Categories	Number of observations	Correlation coefficient
GARMENT TYPES:		
Sleepwear	162	.6754****
Playclothes and casual wear	162	.7876****
Outer wear	162	.7901****
Dressy wear	162	.8303****
Underwear	162	.6576****
Other	162	.5171****
AGE GROUPS:		
Children 1-5	162	.8582****
Males 6-12	162	.9418****
Females 6-12	162	.9425****
Teenagers	162	.8945****
Adults	162	.9050****
Elderly	162	.8677****

****Significant at .0001 level.

Realistic Priorities for FRF

To obtain an appraisal of the women's realistic priorities for the FR characteristic, they were asked to select from the same list of 10 garment and fabric characteristics used in Study I the ones they would be willing to sacrifice to have the FR characteristic in each of the four garment categories for each of the six age-sex groups. As in Study I, a realistic priority score was calculated for each respondent using the Likert technique. The maximum realistic priority score of 240, the same maximum as in Study I, indicated that to have FR protection the respondent was willing to sacrifice all 10 garment and fabric characteristics in all four garment categories for all six age-sex groups. The actual realistic priority scores among the respondents in Study II ranged from 0 to 240, and the overall mean score was relatively low at 48.67.

Pearson product-moment correlations were calculated to explore relationships between (1) total realistic priorities and age-sex and garment subpriorities, and (2) each age-sex and garment subpriority with all other age-sex and garment subpriorities. Total priority scores were compared with scores for (1) specific garment categories, (2) specific age-sex categories, and (3) age-sex group categories within a specified garment category. The subpriority scores were compared with other subpriority scores by (1) specific age-sex groups by other age-sex groups, (2) specific garment categories by other garment categories, (3) specific garment categories by specific age-sex groups, (4) specific garment categories for a specific age group by specific garment category without age restric-

Table 11.—Pearson product-moment correlations between consumers' total realistic priorities for FRF and their realistic priorities for FRF for specific garment types and for specific age groups

Categories	Number of observations	Correlation coefficient
GARMENT TYPES:		
Sleepwear	149	.9107****
Playclothes and casual wear	149	.9274****
Dressy wear	149	.8971****
Underwear	149	.9155****
AGE GROUPS:		
Children 1-5	149	.8650****
Males 6-12	149	.9662****
Females 6-12	149	.9641****
Teenagers	149	.9497****
Adults	149	.9226****
Elderly	149	.8906****

****Significant at .0001 level.

tions, and (5) specific garment category by a specific garment category for a specific age group. These constituted 451 correlation analyses and highly significant ($p<.0001$) correlations occurred in all of these realistic priority analyses. Correlations between the total realistic priority scores and each garment and each age-sex subgroup are shown in Table 11.[8]

Priorities Related to Experience with Burn Victims

Analyses of variance were used to determine if there were differences in the idealistic and realistic priorities among respondents with varying levels of experience with burn victims. There was a highly significant difference ($p<.005$) in total idealistic priority scores and a significant difference ($p<.05$) in total realistic priority scores among the nine levels of experience with burn victims. Generally, those respondents with the most experience with burn victims had the highest idealistic ($\overline{X} = 24.6$ when maximum was 37) and the highest realistic ($\overline{X} = 82.0$ when maximum was 240) FRF priority mean scores.

Idealistic and realistic priority scores were broken down by garment category, and highly significant differences among experience levels were found in the women's idealistic priorities for the FR characteristic in *casual wear, outerwear* (both $p<.001$), and *"other"* FR garments ($p<.005$). Idealistic scores for FR *sleepwear* approached significance ($p<.10$). Analyses of the respondents' idealistic priority scores for the FR characteristic by age categories revealed highly significant differences among experience levels in their priorities for females ages 6 through 12 ($p<.001$), males ages 6 through 12, and children ages 0 through 5 ($p<.005$) and significant differences in priorities for teenagers and adults ($p<.05$). Priority scores for the FR characteristic for elderly persons bordered on significance ($p<.10$). Differences in realistic priority scores among experience levels for FR *sleepwear* were highly significant ($p<.01$) and those for FR *casual wear* were significant when garment categories were analyzed. Differences in scores bordered on significance ($p<.10$) in the *underwear* category. Mean scores in all of the subcategories for respondents with more experience with burn victims were consistently higher than mean scores for respondents with less experience with burn victims.

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[8] The remaining correlation tables were omitted.

The realistic priority scores were also broken down by age categories. Experience with burn victims was a highly significant source of variation in the realistic priority scores for the FR characteristic for the elderly ($p<.005$) and adults ($p<.01$). It also bordered on significance ($p<.10$) for males 6 through 12, females 6 through 12, and teenagers.

The data were further separated into realistic priorities for each garment for each age category. When experience with burn victims was the variable, six highly significant differences occurred. Highly significant differences appeared in mean priority scores for FR *sleepwear* for the elderly and males 6 through 12. Priorities for FR *dressy clothes* for the elderly and for adults also yielded highly significant ($p<.01$) differences. Significant differences in realistic priorities among the various experience levels were found for FR *casual wear* for females 6 through 12 and teenagers, for FR *sleepwear* for adults, and for FR *underwear* for teenagers ($p<.05$). All of these subcategory realistic priority scores were consistently higher for respondents with more experience with burn victims than for respondents with less experience.

Priorities Related to Experience with FRF

The researchers were interested in determining whether the respondents' experiences with FRF influenced their idealistic and realistic priorities for flame retardance. Therefore, analyses of variance were calculated to determine if any differences existed in their idealistic and realistic priorities according to their experience with FR garments. There were significant ($p<.05$) differences by experience in the respondents' idealistic priorities for FR *sleepwear* and *underwear* when the scores were analyzed by garment category. Respondents who had *considered buying* FR *sleepwear* had the highest mean priority scores ($\bar{X} = 5.63$), followed in descending order by those who had *purchased* ($\bar{X} = 4.61$), were *not aware* ($\bar{X} = 4.34$), and were *aware* ($\bar{X} = 4.06$). As with sleepwear, respondents who had *considered buying* FR *underwear* had the highest mean scores ($\bar{X} = 3.63$), but the order of the remaining scores was different, with those who were *not aware* ($\bar{X} = 2.44$) next highest, followed by those who had *purchased* ($\bar{X} = 1.86$) and those who were *aware* ($\bar{X} = 1.69$). When idealistic priority scores were broken down by age groups, a highly significant difference by experience ($p<.005$) occurred in respondents' priorities for the FR characteristic for males 6 through 12 and a significant difference ($p<.05$) occurred in priorities for protection for adults. In both age categories, respondents who had *considered buying* FR garments had the highest mean scores ($\bar{X} = 3.31$, both), followed in descending order by *not aware* ($\bar{X} = 2.49$, $\bar{X} = 2.68$, respectively), had *purchased* ($\bar{X} = 2.49$, $\bar{X} = 2.68$, respectively), and *aware* ($\bar{X} = 2.05$, $\bar{X} = 1.95$, respectively).

When the respondents' experiences with FR garments were analyzed, a significant difference ($p<.05$) in total realistic priorities for FRF appeared. Respondents who had *considered buying* FR garments had the highest mean scores ($\bar{X} = 71.57$), followed by scores of those who were *not aware* ($\bar{X} = 57.67$), who had purchased ($\bar{X} = 47.80$), and who *were aware* ($\bar{X} = 30.68$). When realistic priority scores were broken down by garment categories, a highly significant difference by experience ($p<.01$) occurred in respondents' priorities for FR *sleepwear* and significant differences ($p<.05$) occurred in priorities for FR *underwear, casual wear,* and *dressy wear.* Generally, respondents who had *considered buying* had the highest priority scores, followed by those who were *not aware,* had *purchased,* and were *aware* of FR garments. In the analysis by age groups, significant differences ($p<.05$) were found in the respondents' priorities for FR garments for males 6 through 12, females 6 through 12, and teenagers. For all three age groups, respondents who had *considered buying* had the highest mean scores, followed in descending order by those in the *not aware, pruchased,* and *aware* categories.

When the analysis of realistic priorities among respondents who had different experiences with FR garments was broken down by each garment category by each age-sex group, several differences occurred. Respondents in the various experience levels had highly significant differences in priorities for FR *sleepwear* for males and females 6 through 12 ($p<.005$) and for FR *underwear* for teenagers ($p<.01$). Significant differences among experience levels occurred in respondents' realistic priorities for FR *casual wear* for ages 0 through 5 ($p<.05$), males 6 through 12 ($p<.05$), and teenagers ($p<.05$), and bordered on significance for females 6 through 12 ($p<.06$). Respondents in the various experience levels had significant differences in realistic priorities for FR *underwear* for females 6 through 12 ($p<.05$), for FR *sleepwear* for teenagers ($p<.05$), and for FR *dressy clothes* for females 6 through 12 ($p<.05$), males 6 through 12 ($p<.05$), and adults ($p<.05$). The differences bordered on significance for FR dressy clothes for teenagers ($p<.06$) and the elderly ($p<.10$). In all of these categories, generally, respondents who had *consi-*

dered buying had the highest scores, followed by those who were *not aware,* had *purchased,* and were *aware* of FR garments.

Attitudes and Priorities

Pearson product-moment correlations were calculated between the women's total idealistic priority scores, their total attitude scores, and each of the three component attitude scores — availability of FRF, government regulations of FRF, and time and money sacrifices to have and maintain FRF. These four scores were all highly correlated ($p<.0001$), as shown in Table 12. Highly significant correlations ($p<.0001$) were found for all inter-relationships involving total attitude scores, the three component attitude scores, and the idealistic priority scores for all six age-sex groups. The same trend of highly significant correlations ($p<.002$) continued when inter-relationships were determined between total attitude scores, component attitude scores, and idealistic FRF priority scores for all six of the garment categories, with one exception. The correlation between attitudes toward government regulations and the *"other"* garment category — and this was mostly adult work clothes — was significant ($p<.03$).

All four attitude scores were also correlated ($p<.0015$) with the total realistic priority scores (Table 13). Highly significant ($.0082<p<.0001$) correlations appeared when all four attitude scores were related to realistic

Table 12.—Pearson product-moment correlations of consumers' total idealistic priorities for FRF vs. their attitudes toward FRF

Attitudes	Number of observations	Correlation coefficient
Total attitude	151	.6707****
Attitude toward availability	154	.6673****
Attitude toward government regulations	155	.5839****
Attitude toward monetary and time costs	158	.5521****

****Significant at .0001 level.

Table 13.—Pearson product-moment correlations of consumers' total realistic priorities for FRF vs. their attitudes toward FRF

Attitude	Number of observations	Correlation coefficient
Total attitude	141	.3888****
Attitude toward availability	143	.3540****
Attitude toward government regulations	145	.2680***
Attitude toward monetary and time costs	146	.4142****

***Significant at .001 level.
****Significant at .0001 level.

priority scores for the six age-sex categories. Highly significant ($.0099<p<.0001$) correlations also occurred when the four attitude scores were correlated with realistic priority scores for the four garment categories. When the four attitude scores were related with realistic priority scores for each of the four garment categories for each of the six age-sex groups, highly significant correlations ($.0155<p<.001$) occurred in most of the garment categories for all six of the age-sex groups. The remaining categories yielded significant correlations ($.0333<p<.0166$).

Demographic Characteristics and Attitudes

The same 10 demographic variables in Study I were also explored as possible sources of variation in the attitudes and priorities of respondents in Study II. These variables were marital status, age of respondent, occupation of main wage earner, education of respondent, education of main wage earner, number of children living in the home, presence of males ages 0 through 5 and females ages 0 through 12 in the home, presence of males ages 6 through 18 and females ages 13 through 18 in the home, presence of persons over 65 living in the home, and social class.

There were no statisitically significant differences in the mean total attitude score of the respondents among the categories for any of the 10 demographic variables. The total attitude mean scores used in these analyses of variance did approach significance ($p<.10$) on one variable, familial social class. Respondents from middle class families had the highest mean total attitude score ($\bar{X} = 56.79$), while those from upper class families had the lowest ($\bar{X} = 48.61$).

When each of the three component sets of attitudes was analyzed for each of the 10 demographic variables, only one significant difference occurred. Social class was a significant source of variation ($p<.03$) for consumers' attitudes toward monetary and time costs to obtain and maintain FRF. In this component set, as with the total attitude scores, respondents in middle social class families had the highest mean score ($\bar{X} = 20.62$) while respondents in upper social class families had the lowest ($\bar{X} = 16.73$).

Demographic Characteristics and Priorities

Analyses of variance were calculated to determine if differences existed in the respondents' idealistic and realistic priorities for the FR characteristic when each of the 10 demographic variables was the source of variation.

There were no statistically significant differences for the total idealistic priority scores, but the number of children in the home, a burn propensity variable, bordered on significance ($p<.10$). Respondents with three or more children in the home had lower total idealistic priority scores, on the average ($\bar{X} = 14.07$), than did respondents with two or less children in the home ($\bar{X} = 18.26$).

When the idealistic priority scores were analyzed to determine priorities in each of the six garment categories, marital status of the respondent was a significant source of variation in the idealistic priority for the FR characteristic in *dressy clothes* ($p<.04$) and in *underwear* ($p<.05$). In both categories, respondents who were not married had higher idealistic priority mean scores ($\bar{X} = 2.44$ and $\bar{X} = 2.43$, respectively) than respondents who were married ($\bar{X} = 1.42$ and $\bar{X} = 1.41$, respectively). The older respondents had a significantly lower ($p<.03$) idealistic mean priority score ($\bar{X} = 4.28$) for FR sleepwear than the younger respondents ($\bar{X} = 5.61$). However, when the presence of an elderly person in the home was considered, a significant difference ($p<.03$) occurred in the respondents' idealistic priority mean score for FR *sleepwear.* Respondents who had elderly persons living in their homes had a higher idealistic mean priority score ($\bar{X} = 5.77$) than those who did not ($\bar{X} = 4.46$). The social class factor also bordered on significance ($p<.10$) in the idealistic priorities for FR *sleepwear*. Respondents in the upper social class rankings had the lowest mean priority score ($\bar{X} = 4.34$), while respondents in the middle ($\bar{X} = 5.46$) and lower ($\bar{X} = 5.53$) social class rankings had the highest mean priority score for FR *sleepwear.* The number of children in the home was also a significant ($p<.02$) source of variation in the respondents' idealistic priorities for FR *outer wear.* Respondents with fewer children at home had a higher mean priority score ($\bar{X} = 3.42$) than those with more children at home ($\bar{X} = 1.91$).

Each of the demographic variables was also analyzed to determine associations in the idealistic priority scores for each low and each high burn propensity age group. While not a statistically significant source of variation in idealistic priorities for the three high burn propensity age groups, the number of children in the home was a significant source of variation ($p<.04$) in the idealistic priorities for FRF for one low propensity group, adults, and it approached significance ($p<.09$) for another, teenagers. In both instances, respondents with fewer children at home had higher idealistic priority mean scores ($\bar{X} = 3.15$ and $\bar{X} = 2.63$, respectively) for FRF than respondents with more children at home ($\bar{X} = 2.12$, and $\bar{X} = 1.84$, respectively). Differences in idealistic priority scores for FRF for males ages 6 to 12 bordered on significance ($p<.10$) when social class was the variable. Respondents in the upper social class rankings had a lower priority mean score ($\bar{X} = 1.68$), while respondents in the middle ($\bar{X} = 2.64$) and lower ($\bar{X} = 2.87$) social class rankings had higher priority mean scores.

The total realistic FRF priority scores of the respondents were analyzed to determine if the same 10 demographic variables explored in the idealistic priorities analyses served as significant sources of variation in these realistic priorities. The presence of males ages 0 through 5 and females ages 0 through 12 in the home was a significant source of variation ($p<.03$) in the respondents' total realistic priorities for FR garments. Respondents who had no children in these age groups had a higher realistic priority mean score ($\bar{X} = 71.61$) than did those who had children in these age groups ($\bar{X} = 49.34$). The respondents' marital status yielded priorities for FR garments which bordered on significance ($p<.06$). Unmarried respondents had a higher priority mean score ($\bar{X} = 70.71$) than did married respondents ($\bar{X} = 50.25$).

Analyses of variance were computed to determine differences by demographic variables in realistic FR priorities for each of the six garment categories. The presence of males 0 through 5 and females 0 through 12 in the home yielded a highly significant difference ($p<.01$) in the respondents' priorities for the FR characteristic in *underwear*, a significant difference ($p<.03$) in priorities for this characteristic in *sleepwear,* and a difference bordering on significance ($p<.08$) in priorities for this characteristic in *casual wear*. In all of these garment categories, respondents with children in these two age groups had a lower realistic priority mean score than did respondents who did not have children in these age groups. The realistic priority mean scores according to marital status of respondents were significantly different for FR *dressy clothes* ($p<.03$) and they bordered on significance ($p<.06$) for FR *casual wear*. The unmarried women's priorities for the FR characteristic in fabrics in these two garment categories ($\bar{X} = 16.08$ and $\bar{X} = 16.61$, respectively) were higher than the priorities of married respondents ($\bar{X} = 10.15$ and ($\bar{X} = 11.29$, respectively). Age of the respondents, although not a significant source of variation, bordered on significance ($p<.09$). Respondents who were 18 through 34 years old had higher mean realistic priorities ($\bar{X} = 19.70$) for FR *underwear* than those who were 34 through 54 years old ($\bar{X} = 13.35$) or 55 and older ($\bar{X} = 13.52$).

The data were analyzed to determine if any of the demographic variables were associated with the respondents' realistic priorities for each of the low and each of the high burn propensity age groups. The presence of males 0 through 5 and females 0 through 12 in the home was a significant ($p <.05$) source of variation in their realistic priorities for all three of the high burn propensity age groups and one of the low propensity age groups, males 6 through 12. The presence of teenagers in the home also was a source of variation that bordered on significance ($p <.07$). As seen previously, those respondents who did not have male children 0 through 5 and female children 0 through 12 in the home had the higher mean realistic priority score for FR garments, while those who did have children in these age groups had the lower mean priority score. Marital status was a highly significant source of variation ($p <.01$) in the respondents' realistic priorities for the FR characteristic for the elderly, a significant source of variation ($p<.05$) for the FR characteristic for adults, and a source bordering on significance for teenagers (p <.07). Unmarried respondents' scores were higher, on the average, than married respondents' scores.

Analyses of variance were run to determine differences by demographic variables in the women's realistic priorities for FR protection in each garment category for each age-sex group. Marital status was a highly significant (p <.01) source of variation in the respondents' realistic priorities for FRF in *dressy clothes* and *sleepwear* for the elderly, and a significant (p <.05) source of variation in their priorities for FR *underwear* and *casual wear* for the elderly and for *casual wear* and *dressy clothes* for adults and teenagers. It also bordered on being significant (p<.10) for FR *dressy clothes* for males 6 through 12 and FR *underwear* for adults. Unmarried respondents had higher realistic priority mean scores for the FR characteristic in all of these garment and age categories than did married respondents. The respondent's age was a significant source of variation (p<.05) in priorities for FR protection for *underwear* for females 6 through 12 and bordered on being significant for *underwear* for children ages 0 through 5 (p<.07) and males ages 6 through 12 (p<.06). Younger respondents had higher mean scores than did older respondents in this garment category for all three of the age groups. The presence or absence of males ages 0 through 5 and females ages 0 through 12 in the home was a highly significant source of variation (p<.01) for the respondents' preference for FR *underwear* for the elderly and for teenagers. Significant differences (p<.05) were found in these respondents' priorities for FR *underwear* for children 0 through12; *sleepwear* for males 6 through 12 and the elderly, and *casual wear* for males 6 through 12. Differences bordering on significance (p<.10) were found for *casual wear* for females 0 through 12 and the elderly; *sleepwear* for ages 0 through 5, females 6 through 12, and teenagers; *underwear* for adults; and *dressy clothes* for ages 0 through 5. All analyses revealed that respondents who did not have children, males 0 through 5 and females 0 through 12, had higher realistic priority mean scores for FR garments than did respondents who had children in these age groups. The difference in realistic priority scores of respondents with and without males ages 6 through 19 and females ages 13 through 19 in the home bordered on significance (p<.09) for FR *dressy clothes* for ages 0 through 5. Scores were higher, on the average, for respondents who did not have children in these age groups living at home than for those who did.

Summary and Implications

It was believed that consumer behavior regarding FRF would be related to knowledge about the product, based upon its visibility and availability. However, in Study I neither the attitudes, experiences, nor priorities of the women regarding FRF were related to their knowledge about FRF and the FFA. This probably occurred because their knowledge was low due to limited availability of FRF.

Study I respondents' lack of knowledge regarding appropriate laundering techniques, and their comments that FR finishes "won't last," suggest that mandatory FR products will not prevent burn injuries unless consumers are educated to care for the products correctly. Less than half of the women in Study I were aware of the Permanent Care Trade Rule. Mandatory care labeling probably will not be sufficient to educate these women to care for FRF.

In Study II, providing information about the FFA and FR garments apparently had only a minimal influence on consumer attitudes toward and priorities for the FR characteristic, since there were no significant differences between respondents in the two treatment groups. Consumers have been exposed to FRF in children's sleepwear for 7 years, and the women in Study II may have accepted these FR garments as something over which they had no control. Information about the carcinogenic potential in saccharin and in the Tris finish was published by the national media the same week the questionnaires for Study II were mailed. This also could have had an impact on the women's opinions regarding the FR characteristic. From the women's personal comments it was apparent that they were equating the problems with the Tris finish with all FR finishes. Yet Tris was used primarily on polyester, acetate, triacetate, and blends of these fibers. Reacting to incomplete information probably has had an impact on all FR treated garments and further magnified the textile and clothing industries' problem in fostering consumer acceptance of a product for which many consumers feel little need. However, consumers are becoming concerned about increasing government control over their private lives, particularly the elimination of the right to choose between products. The lower scores in the government regulation and availability attitude categories in both Study I and Study II are indicative of this concern, and personal comments from the women reinforced this contention.

The respondents' experience with burn victims was an important factor in increasing their desires for the FR characteristic as reflected in personal comments from respondents in Study I. Then, in Study II, about half the respondents had had some experience with burn victims, and their attitude and priority scores were consistently higher than the scores of those with no experience with burn victims.

The idea that consumer behavior is related to product availability was reflected in the FRF experience data. Among those women who had purchased FR garments, more of them had children residing in their households, and this purchasing was especially evident among those who had younger children. More of the younger women, those most likely to have young children, had purchased FRF. Obviously these purchases were confined to children's sleepwear sizes 0 to 14, a relatively low-volume item. Consumers will have a wider scope of potential experiences with FRF available when a wider range of FR products is available, and this will probably influence their knowledge of and attitudes toward FRF.

Increased exposure to FR finishes, which will result as additional standards for FRF are implemented, may not, however, increase consumers' priorities for FRF. Indeed, in both studies some of the respondents with no experience with FRF had significantly higher priority scores than those who had purchased FRF. This seems to indicate that experience with FRF may actually reduce the desire for the FR characteristic, especially if certain other fabric characteristics must be relinquished to have it. For example, in Study I the older and more educated women placed higher priorities on the importance of the FR characteristic. Yet some of the younger, less educated persons may have families with the greatest tendencies to be burn victims. In Study II, respondents who had purchased FR garments, respondents who were married, and respondents with younger children in the home generally had lower attitudes and priorities for the FR characteristic than the other women had. The tendency for respondents in these categories to have family members in the high burn propensity age groups is high. One might expect this tendency to influence higher priorities for the FR characteristic, but it did not in Study II.

The economic pressures on contemporary families may have a bearing upon preferences for FR garments. In Study II, married respondents, respondents with large families, and respondents dependent on main wage earners in clerical, sales, or skilled occupations generally had lower attitude and priority scores for FRF than other respondents. These respondent characteristics indicate lower income levels or higher expense levels for families. These income and expense levels, combined with inflationary pressures, may contribute to a resistance to higher prices for any product, including FR garments. Many contemporary families are two-income families, and the extra time required to care for garments with FR finishes may be less attractive when both the husband and wife work.

Convincing consumers that it is worth spending extra time and money to acquire and maintain FRF will be a massive educational task. This aspect will create some of the greatest problems when the FFA is enforced in a wide range of products, especially among some of the groups with the greatest need for FRF. For example, in Study I several of the demographic variables related to the propensity to be burn victims were related to the consumers' attitudes toward monetary and time costs for FRF. The younger mothers had positive attitudes toward having the FR characteristic, but they had negative attitudes toward sacrificing time and money for FRF. Those women with the least education were the least willing to sacrifice time and money for FRF. Social class was not related to attitudes toward the FR characterisitic, probably because the women in the highest education level as well as those in the lowest level were unwilling to sacrifice time and money. The older women were willing to spend time and money to have FRF, but they did not believe the FR characteristic was important.

The women in both studies had very low realistic priorities for the FR characterisitic if it meant other garment and fabric characteristics had to be relinquished, even though they placed a somewhat higher idealistic priority value on the FR characteristic. Apparently, the protection offered by FR finishes will be accepted as a desirable garment characteristic only when it is offered in addition to the characteristics presently available.

The findings in Study I suggest that consumers are virtually unaware of the potentially sweeping application of the FFA, and that they know little about FRF. As their knowledge increases, their attitudes toward and priorities for FRF may change. The lower attitude and priority mean scores in Study II after the Tris issue was widely publicized suggests that the attitudes and priorities may be in the direction of less consumer acceptance of FRF unless a more positive image of FRF and a greater need for the FR characteristic is presented to the public.

The data in both Study I and Study II suggest that consumers want the option of choosing FRF rather than having FRF mandated by federal legislation. Some FR products are more likely than others to attain widespread consumer acceptance if this option becomes available. The types of consumers who will adopt FR products voluntarily, especially if they must relinquish other desirable fabric characteristics to have the FR characteristic, may not be those whose families have the greatest propensity to be burn victims.

To date, the mandated FR characteristic in fabrics has been enforced in a garment category with a rather low sales volume, children's sleepwear sizes 0 to 14. Thus, the impact on the textile and clothing industries, as well as consumers, has been minimal. As standards are established and extended to other garment categories and other age levels, the full impact of the FFA on consumers and on the textile and clothing industries will be reflected in sales of textiles and clothing.

Literature Cited

1. American Apparel Manufacturers Association. *Fire Incidents Involving Sleepwear Worn by Children Ages 6-12*. Washington, D.C.: U.S. Government Printing Office, Catalogue No. C1346, 1972.
2. "A Progress Report: Children's Flammable Sleepwear." *Consumer Reports* (February, 1972), 106.
3. "At Home and at Play," *Clothes*, 9 (January 1, 1975), 87.
4. Beal, George M., and Everett M. Rogers, "Informational Sources in the Adoption Process of New Fabrics." *Journal of Home Economics,* 49 (October, 1957), 630-634.
5. Blagman, Burton. "Consumer Protection: Fact or Myth?" *American Dyestuff Reporter,* 63 (March, 1974), 56-57.
6. Bohlen, J.M. "Research Needed on Adoption Models," in Wilbur Schramm and Donald F. Roberts, eds. *The Process and Effects of Mass Communication*. Urbana, Illinois: University of Illinois Press, 1972.
7. "Boys Sleepwear Survey — Smoke Signals," *Clothes*, 9 (January 1, 1975), 78.
8. "Caution: Ignoring FR May Be Hazardous," *Clothes,* 9 (January 1, 1975), 87.
9. *Cole's Directory*. Cross Reference Directory, *City*. Lincoln, Nebraska: Cole Publications, Inc., 1975.
10. Finely, E. L. "Flame Behavior of Multilayer Garments." AATCC 1974 National Technical Conference. New Orleans, October 11, 1974.
11. "Flame Retardancy." *American Fabrics and Fashions,* 102 (Fall, 1974), 53-54.
12. "Flammability: Progress Despite Bureaucratic Roadblocks." *Textile Industries,* 139 (August, 1975), 135-144.
13. "Flammability: The Steps that Lead to Higher Price Points." *Clothes,* 8, (January 15, 1974), 43.
14. "FR Poly/Cotton: Dream or Reality?" *Clothes,* (November 1, 1974), 25.
15. Harries, Nancy. "Textile News: Fabric Flammability." *Family Economic Review,* (Fall, 1974), 11.
16. Havland, C.I., James, I.L., and Kelley, H.H. *Communication and Persuasion*. New Haven, Connecticult: Yale University Press, 1959.
17. Hollingshead, A.B. *Two Factor Index of Social Position*. New Haven, Connecticut: Box 1965, Yale Station, author, 1957. (Mimeographed).
18. Holloway, Imogene and Houston, Betty. "The Flammable Fabrics Issue." *Journal of Home Economics,* (March, 1974), 19.
19. Howry, K.A. "We Don't Know Much — About Fabric Flammability." *Modern Textiles,* 50 (August, 1969), 56-61.
20. Likert, R. "The Method of Constructing an Attitude Scale." in Gary M. Maranell, ed. *Scaling: A Source-book for Behavioral Sciences*. Chicago: Aldine Publishing Co., 1974.
21. Moyer, C. A. "The Sociological Aspects of Trauma." *The American Journal of Surgery,* 87 (March, 1954), 421-430.

22. Perkins, R.M., Drake, G.L., and Beninate, J.V. "Rot Resistance of Cotton Fabric Treated with Various Flame Retardants." Proceedings of the Eighth Cotton Utilization Research Conference, New Orleans, May 1-13, 1968. Agricultural Research Service, USDA, 76.

23. Scotese, P.G. Marketing Portion of the Textile Industries. Proceedings of the Fourth National Meeting of the Association of College Professors of Textiles and Clothing. Charlotte, North Carolina, October, 1971, 12-17.

24. Suchecki, S. "Focus on Flammability: Progress at a Price," *Textile Industries*, 138 (September, 1974), 49.

25. Wasson C.R. *Consumer Behavior: A Managerial Viewpoint.* Austin, Texas: Austin Press. 1975.

26. Wright M.T. Relation of Burning Injuries to Social Circumstances." *The Lancet,* 2-18, (February 3, 1945), 155.

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